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ABSTRACT

This volume contains the lesson plans and appropriate teacher background material for a 37-lesson sequence on the nervous system in health and medicine. Additional material is provided for supplementary lessons on concepts of electricity. Associated material, contained in separate volumes, include a student text and a student laboratory manual. Each lesson outline includes a rationale, objectives, sequence of student text lessons and laboratory activities, suggestions, teaching notes, materials (where appropriate), and anticipated results. (RE)

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BIOMEDICAL SCIENCE

UNIT IV

THE NERVOUS SYSTEM IN HEALTH AND MEDICINE

THE NERVOUS SYSTEM; DISORDERS OF THE BRAIN AND NERVOUS SYSTEM; APPLICATION OF COMPUTER SCIENCE TO DIAGNOSIS; DRUGS AND PHARMACOLOGY; THE HUMAN SENSES; ELECTRICITY

INSTRUCTOR'S MANUAL
REVISED VERSION, 1976

THE BIOMEDICAL INTERDISCIPLINARY CURRICULUM PROJECT

SUPPORTED BY THE NATIONAL SCIENCE FOUNDATION

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INTRODUCTION

Unit IV considers the nervous system and related health problems. Neural control of the body systems studied in previous units is emphasized in this unit in order to integrate the earlier material. Computer science is introduced and applied to the diagnosis of brain disorders. A sequence of lessons on drugs is included, in part because of the important role of many drugs in the functioning of the nervous system. The human senses are also presented because they are physiologically closely related to the nervous system. Finally, a group of lessons on electricity is located at the end of this unit. These lessons may be taught at any convenient time prior to the beginning of Unit V.

Much of modern medicine is concerned with disorders of the nervous system and disorders that involve the senses. For example, strokes were the third leading cause of deaths in the United States in 1973. Also, epilepsy, a relatively unpublicized brain disease, affects approximately 1% of our population. Dysfunctions involving vision are even more prevalent--more than 60% of the world population have some kind of visual defect. Unit IV will explore these and many other health problems.

A. CONTENT OF THE UNIT:

A brief description of the major sequences of lessons follows.

PART I: THE NERVOUS SYSTEM (Lessons 1 through 8)

The initial lesson of the unit explores the anatomy and functions of the brain. Lesson 2 considers the structure of neurons and the nature of nerve impulses. Brain waves and epilepsy (a disorder associated with atypical brain-wave patterns) are discussed in Lesson 3. In the laboratory, the students examine their brain-wave patterns. In the following activity, students have an opportunity to try to modify their brain-wave patterns (as well as heart rate and skin temperature) by biofeedback training. Lesson 5 considers the nature of reflexes and the use of reflex tests in diagnosis. Multiple sclerosis, a disease that is indicated by atypical reflexes, is covered in this lesson. The nature of cerebrospinal fluid (CSF) and the clinical uses of CSF are explored in Lesson 6. Cerebral hemorrhage is included as an example of a brain disease that may be detected by the analysis of CSF. Cerebral thrombosis is then discussed in Lesson 7. Psychometric tests are also considered in this lesson, since they are used to assess brain damage that affects mental functions such as memory and concentration. Lesson 8, on brain tumor, completes the first part of Unit IV. This lesson considers how brain tumors may be detected by visual-field examination.

The discussion of a variety of brain disorders in Lessons 3, 5, 6, 7 and 8 provides background information needed for the computer lessons.

PART II: CONSTRUCTION OF A DIAGNOSTIC COMPUTER FOR BRAIN DISEASE (Lessons 9 through 13)

This sequence applies the symbolic logic treated in Lessons 1 through 8 of Mathematics Unit IV to the design and construction of a diagnostic computer for brain disease. The sequence is introduced by a review of the findings associated with five of the brain diseases studied in Sections 3 through 8. There is also an activity in which the students use techniques learned in Mathematics to construct a diagnostic truth table for the five diseases. The remaining activities guide the students through the process of converting this truth table into logic statements, which are then used to design the circuitry for a simple computer. The laboratory activities begin by introducing the students to a variety of logic gates and culminate in the students' using these gates to construct the diagnostic computer.

PART III: DRUGS AND PHARMACOLOGY (Lessons 14 through 20)

Lesson 14 introduces the sequence of lessons on drugs and pharmacology. This lesson focuses on drugs derived from natural products, and in the laboratory activity the students make some pharmaceutical preparations from plant sources. In Lessons 15 and 16, the field of pharmacology is introduced. The major classes of drugs are discussed. Lesson 17 explains the steps that lead to prescription of a drug by a physician. The stress in this lesson is on antibiotics and antibacterial agents, since most of the laboratory activities included in this part of the unit are concerned with antibiotics (i.e., Microorganisms from the Soil; Testing Antibacterial Agents; Testing the Antibiotic Activity of Penicillium; Testing the Effectiveness of Antibacterial Agents). Lesson 18 considers the importance of placebos in medical research and medical practice. The last two lessons in this sequence deal with several important psychoactive drugs: alcohol, opiates, cocaine and marijuana. These lessons consider the uses of each of these drugs and the health problems sometimes associated with them.

PART IV: THE SENSES (Lessons 21 through 37)

This sequence of lessons on the human senses may be viewed as having three subsections: sound and hearing (Lessons 21 through 25), light and vision (Lessons 26 through 35) and the other senses (Lessons 36 and 37).

Lesson 21 compares transverse and longitudinal waves. In the laboratory, the students analyze wave patterns generated with a Slinky. In addition, they begin to conduct pure-tone audiometric tests. This activity continues for several days. Lesson 22 considers the anatomy of the ear and the auditory canal. The students construct an otoscope for viewing the eardrum and perform the Rinné Test (a test used in the diagnosis of hearing dysfunction). Several causes of hearing loss are considered in Lesson 23. In the laboratory, students determine the speed of sound by the resonant method. Lessons 24 and 25 consider the anatomy of the organs of speech production and the ways in which the different sounds are made. In LA-24, students produce standing waves in strings and examine the factors that determine the pitch of speech sounds.

Lessons 26 and 27 introduce a series of lessons on light and vision with a basic treatment of the nature of light. The principle of diffraction is then applied in the laboratory to measure the wavelengths of light of different colors. In LA-27, the nature of color perception is examined by viewing a light source through filters. Refraction of light is the main topic of Lessons 28 and 29. In the accompanying activities, the indices of refraction are determined for different media. In LA-29 and 30, the students construct lenses and obtain data with these lenses to determine their focal lengths. ST-30 provides the information needed to calculate the theoretical focal length. Lessons 31 and 32 consider visual perception as related to the anatomy of the eye, and in the laboratory a dissection activity (LA-31) is provided. In Lessons 32 and 33, there is no laboratory activity scheduled. Instead, the students are assigned to do a library study and to report on health problems related to vision. ST-33 discusses the Snellen Test for visual acuity. The students administer this test in Lessons 34 and 35, both to one another and to a class of elementary-school children. ST-34 provides a discussion of the mean, median and mode. These statistical measures are needed to evaluate the Snellen Test data.

Lessons 36 and 37 compose a brief introduction to the senses other than sight and hearing and complete the longer sequence of lessons on the senses. In these two lessons, the senses of taste and smell and the kinesthetic senses are explored. In LA-36, the students determine their "two-point thresholds" (the minimum distance on a particular part of the body between two simultaneous touches that can be perceived as two touches rather than one). In LA-37, the students determine their taste sensitivity to sweet and salty solutions.

SUPPLEMENTARY LESSONS ON ELECTRICITY: (Lessons A through E)

This sequence of lessons is intended as an introduction to electricity. The basic principles of electricity are presented in Lessons A through C. Lessons D and E are concerned with electrical safety and electric shock. In the accompanying activities, the students construct simple circuits and use the BIP to measure the resistance of the skin on different parts of the hand and arm.

B. UNIT OBJECTIVES:

The student will:

- describe at least five important disorders of the nervous system.
- list the principal function of at least three parts of the brain.
- describe the movement of an impulse in a neuron and from one neuron to the next.
- demonstrate brain-wave patterns using the BIP.
- describe at least two clinical applications of biofeedback training.
- compare and contrast the central nervous system and the autonomic nervous system.
- list at least two examples of reflexes and describe the pathway of a nerve impulse in a reflex arc.
- list at least two clinical tests on cerebrospinal fluid and state how these tests are used.
- explain how visual-field tests and psychometric tests are used in diagnosis of brain disease.
- explain how a computer can be used in medicine.
- write a simplified truth table relating eight findings (continuing brain dysfunction, blood in CSF, high total-protein concentration in CSF, high globulin concentration in CSF, high CSF pressure, rapid onset, progressive onset, abnormal skull X-ray) to five diseases (multiple sclerosis, cerebral thrombosis, cerebral hemorrhage, epilepsy and brain tumor).
- design and build a diagnostic computer for five brain diseases using the information from the truth table they construct.
- write the switching functions of the following logic gates: 2-AND, 2-NAND, 2-OR, 2-NOR, 4-NAND, 8-NAND and INVERT.
- solve problems involving the construction of equivalent circuits using combinations of 2-input and INVERT gates.
- give examples of at least three drugs derived from natural products.
- state the action of drugs in at least nine of the following categories: analgesic, antacid, antibiotic, anticonvulsant, antidiarrhetic, cathartic, depressant, hypnotic, narcotic, sedative, stimulant, vasodilator.
- describe the steps by which a physician decides whether drug therapy is indicated.
- list at least three antibacterial agents and describe how they function.
- describe at least two applications of placebos in medicine or medical research.
- describe at least two short-term effects of alcohol use and at least two long-term effects of chronic use of alcohol in large doses.
- compare alcohol, opiates, cocaine and marijuana with regard to habituation, addiction, tolerance and withdrawal.
- list the major health problems associated with the use of opiates.

- apply sterile technique to test the effects of antibacterial agents upon bacteria.
- state the difference between transverse and longitudinal waves.
- list at least four anatomical components of the ear and their functions.
- list at least three common causes of hearing loss.
- give an example of each of the following: plosive, fricative, voiced sound, unvoiced sound.
- state at least two differences between light and sound.
- explain what is meant by "in phase" and "out of phase" waves.
- conduct a Rinné test and a pure-tone audiometric test.
- state Snell's Law.
- draw a diagram to illustrate how a convex lens converges rays of parallel light.
- define each symbol in the following formula and explain how the formula is used: $\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$.
- list and state the functions of at least five anatomical parts of the eye.
- describe the Snellen Test and how it is used in vision screening.
- explain how the lens of the eye inverts an image.
- describe at least four visual disorders and what is done to correct each.
- determine the mean, median and mode when given a list of numbers.
- list the five traditional senses and at least three other senses.
- explain what is meant by the "kinesthetic" sense.
- state the relationship between electricity, energy and electrons.
- state how the resistance of a wire is affected by its diameter, length and temperature.
- state Ohm's Law.
- list at least two common causes of electric shock and how electric shock may be prevented.

C. INTERDISCIPLINARY TIES:

1. Biomedical Mathematics: Unit IV is an exceptional unit in that the Mathematics-Science ties are crucial to successful teaching of the unit in both disciplines. Some of these ties are explained in individual lessons; but the links between Science and Mathematics in the computer sequence, in the lessons on sound and hearing and in the lessons on light and vision merit special emphasis, as explained below.

a. The symbolic logic used in the sequence on construction of a diagnostic computer is taught in Sections 1 through 8 of Mathematics Unit IV. Since it is important that the Mathematics treatment be completed before the Science sequence begins, close communication with the Mathematics instructor is advised. The Science sequence also provides a good opportunity for team teaching if the Mathematics instructor is free during any of the appropriate Science periods.

b. The Science lessons on sound and hearing are based on skills in trigonometry developed in Unit IV, Biomedical Mathematics. Mathematics Lesson 25 must be presented before LA-21. The closer the connection the better.

c. Some of the Science laboratory activities on light and vision provide data that are interpreted in the Mathematics class.

(1) The "floating" Mathematics sequence X1-X4 should begin the same day as Science Lesson 28 or as soon as possible thereafter.

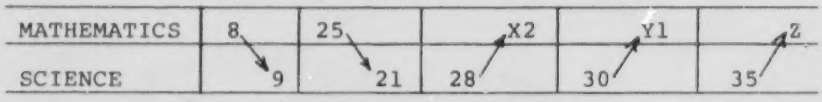
(2) The "floating" Mathematics sequence Y1-Y3 should begin the same day as Science Lesson 31 or as soon as possible thereafter.

(3) The "floating" Mathematics Lesson Z should be presented as soon as possible after Science Lesson 35.

It may be necessary to fill in several Science periods to maintain the optimal sequencing. If the Mathematics lessons lag behind the Science lessons, at least two alternatives may be considered. First, the supplementary lessons on electricity (Lessons A through E) may be used at any time before beginning Unit V. Secondly, Science Lessons 36 and 37 may be taught earlier in the Unit.

The ties between Science and Mathematics may be more easily understood from the following diagram.

LESSONS



2. Biomedical Social Science: Social Science Unit IV includes several lessons that are closely related to Science Unit IV. The relations between the two courses are briefly described below.

a. Supplementary Lesson: This lesson is designed to be used in Social Science soon after you have taught Science Lesson 5. The Science lesson introduces a clinical situation in which a doctor must decide what and when to tell a patient about the possibility that the patient has a progressive and incurable disease (multiple sclerosis). The Supplementary Lesson in Social Science, "The Doctor's Dilemma," provides strategies for helping students explore the value conflicts inherent in this kind of situation. You and the Social Science instructor should coordinate the scheduling of these two complementary lessons.

b. Lessons 16 through 21: In this Social Science sequence students investigate the question, "What influences human behavior with regard to drug use?" The sequence as a whole is therefore complementary to Science Lessons 14 through 20, in which students investigate the question, "What are drugs and how do they affect the nervous system and other parts of the body?" In addition to coordinating your efforts regarding the two Social Science lessons in this sequence mentioned specifically below (Lessons 18 and 20), it is recommended that you and the Social Science instructor discuss these two complementary sequences of lessons before either sequence is taught, in order to identify ways to reinforce the ties between the two sequences.

c. Lesson 18: In this lesson students will be compiling and tabulating data obtained in response to a survey that they and the Social Science instructor have conducted. The survey asks respondents' opinions about the use of various drugs by high-school students; the respondents include the parents of Biomedical students, a sample of students in the school and a sample of teachers in the school.

The data resulting from this survey will be voluminous, and the tasks involved in tabulating the data are complex and time-consuming. It is recommended that both the two Science periods and the Social Science period on the day of Social Science Lesson 18 be set aside for tabulating these data, and that both you and the Social

Science instructor preside over the students' activities. The two of you should coordinate your efforts in scheduling this extended data-tabulating activity. Detailed instructions for tabulating the data are included in the Social Science Instructor's Manual for Lesson 18. It is recommended that both instructors become familiar with these instructions before the lesson is taught.

d. Lesson 20: In this lesson students will generalize from the results of their survey of students, teachers and parents regarding high-school students' drug use. Past experience with this lesson has shown that the results of the survey may be very interesting and even controversial. The interest generated by the survey results might be used to motivate a discussion in the Science class, scheduled sometime following Social Science Lesson 20. Specifically, you might ask students to speculate on the causes and consequences of any discrepancies they may have identified between (1) the pharmacological properties and consequences of use of alcohol, amphetamines, barbiturates, cocaine, marijuana, opiates and tobacco, and (2) the depth of feeling in the community against (or for) the use of any of these drugs by high-school students. Such a discussion might serve (1) to review the material on drugs presented in Science Lessons 14 - 20 (and the information about tobacco smoking presented in Science Units I and III) and (2) to reinforce the complementarity of the sequences of lessons on drugs in Science and Social Science. It is recommended that you and the Social Science instructor discuss the possibility of your conducting such a review lesson some time soon after the teaching of Social Science Lesson 20.

e. Lessons 28 and 29: In these lessons students design messages intended to influence other people's drug-use behavior, in the interest of reducing their risk of getting diseases. The Social Science instructor and the students will need your assistance in two aspects of this activity: (1) a review of the information from Science Lessons 14-20 about consequences of the use of alcohol, cocaine, and opiates, and information from Science Units I and III about the consequences of tobacco smoking; and (2) evaluation of the accuracy of the information students put into their messages, after the messages have been designed. You may also be able to help the Social Science instructor by recommending resource persons who can help students identify ways in which they can improve either the accuracy or the effectiveness of their messages.

f. Unit V Supplementary Lesson: Social Science Unit V includes a supplementary ("floating") lesson that introduces to students several ways in which they can assess the trustworthiness of articles and books about the effects of drug use. You and the Social Science instructor should coordinate your efforts in scheduling this lesson for an appropriate day about the time of presentation of Science Lesson 20 or as soon as possible thereafter.

D. CAREER INFORMATION:

Biomedical Science Unit IV has many career implications. Thus field trips to visit specialists or visits by health professionals to the classroom can be a worthwhile supplement. To make the best use of outside help (i.e., speakers, hosts for field trips, consultants), the following table may be useful.

SPECIALIST	RELEVANT LESSON(S)
Neurologist	1 to 9, 19, 20, 32
Physiological psychologist	1, 18
Physiologist	2, 4, 22, 24, 31, 32, 36, 37
Biophysicist	2, A to E
EEG technician	3
Ophthalmologist	5, 8, 33, 35
Optometrist	5, 8, 33, 35
Medical technologist	6
School counselor or special education teacher	7
Physical therapist	8
Speech therapist	8
X-ray technician	8
Ultrasound technician	8

SPECIALIST	RELEVANT LESSON(S)
Computer programmer	10 to 13
Computer technologist	10 to 13, A to E
Ethnobiologist	14
Pharmacologist	14, 19, 20
Pharmacist	15, 16
Medical microbiologist	15, 17
Medical social worker	19, 20
Drug counselor	19, 20
Audiologist	21, 23
Otorhinologist	22, 23
Speech pathologist or speech therapist	24, 25
Optician	29, 30
Statistician	34
Food technologist	37
Medical electronics technician	A to E
Biomedical engineer	A to E

E. LABORATORY ACTIVITIES REQUIRING ADVANCE PLANNING:

1. Animal brains are needed for LA-1. If you plan to use fresh brains in this activity, plan to order at least one preserved brain as a supplement. Fresh brains are likely to be damaged during processing and may have some parts missing.

2. Live Nitella and live bacteria are needed for LA-2 and LA-16 to 20, respectively. The Nitella may be obtained from a pet shop with aquarium supplies one to two days before LA-2, or they can be ordered in advance. The bacteria should be ordered to arrive about a week before LA-16.

3. An oscilloscope is either suggested or required for the following activities: LA-2, 3, 4 and 25. (An oscilloscope is also needed in Biomedical Mathematics Lessons 23, 24 and 28. The Mathematics instructor may need your help in locating an oscilloscope.)

4. LA-5 calls for preparation of reflex hammers. This should be done at least a day in advance of the activity to allow sufficient time for the silicone rubber to cure. You may wish to involve students in the preparation.

5. Activity 7 requires preparation of transparencies or slides prior to the activity as explained in the relevant teaching notes.

6. In order to present the computer sequence, it is essential that you become familiar with the symbolic logic sequence in the Mathematics Student Text. In addition, advance practice in constructing the brain-disease computer will be extremely helpful. Note that when these activities are actually in progress, it may not be convenient to practice wiring since most of the equipment is likely to be in use by the students.

7. Microbiology laboratories such as LA-16, 18, 19 and 20 are somewhat demanding in terms of preparation time. Suggestions to reduce preparation time may be found in the teaching notes for these activities. For example, there is both educational and practical value in having students do as much of the preparatory work as possible. In addition, you may consolidate the preparations for several laboratory activities. Thus, instead of preparing tubes of nutrient agar for LA-16, LA-19 and LA-20 on three separate days, you can make them all at once. Finally, if necessary, you might eliminate LA-19 or LA-20 without losing the essence of the series.

8. The placebo activity in Lesson 18 requires time in an earlier activity, possibly Lesson 14. Further directions are included in the appropriate lessons.

9. In the activities on sound and light, several materials are required that may need to be borrowed or obtained from a non-routine source. Suggestions are

given for obtaining these materials in the appropriate lessons. These items include audiometers and slinkies (LA-21), bulbs and hand magnifiers (LA-22), speakers (LA-24), diffraction gratings (LA-26) and acetate filters (LA-27).

10. Preliminary work on the preparation of lenses for LA-30 should begin a few days early. The procedure for making lenses is described in LA-29. The first lenses made will be likely to leak, in which case they will need to be resealed. It takes a day for the silicone rubber to cure.

11. Six sets of Snellen cards are needed for LA-34 and LA-35. Satisfactory cards can be made by students.

12. The elementary-school field trip associated with LA-35 should be scheduled well in advance of the activity.

F. BIBLIOGRAPHY:

The books listed in the Instructor's Manual in Units II and III by the following authors will also be useful in this unit: Keeton; Langley; Pansky; de Coursey; Landau; Krueger, et al; Ganong; Wintrobe.

In addition, the following sources were among those used in writing this unit.

A.J. Vander, J.H. Sherman and D.S. Luciano, Human Physiology, 2nd Ed., McGraw-Hill Book Co., N.Y., 1975.

N. Calder, The Mind of Man, Viking Press, N.Y., 1970.

L.A. Stevens, Explorers of the Brain, Alfred A. Knopf, N.Y., 1971.
B. Brown, New Mind, New Body, Bantam Books, N.Y., 1974.
F.H. Meyers, et al, Review of Medical Pharmacology, 2nd Ed., Lange Medical Publications, Los Altos, Ca., 1970.
L. Goodman and A. Gilman, The Pharmacological Basis of Therapeutics, 5th Ed., Macmillan Co., N.Y., 1970.
E.M. Brechér, Licit and Illicit Drugs, Little, Brown and Co., Boston, 1972.
Physician's Desk Reference, 27th Ed., Medical Economics Co., Oradell, N.J., 1973.

A first-year college physics book may also be useful during the sequences on sound and light and on electricity.

G. GENERAL SUGGESTIONS:

1. You may wish to provide bulletin-board space for newspaper clippings related to Unit IV.

2. It should be possible to obtain supplementary literature and/or films for various lessons, such as Lesson 8 on brain tumors (American Cancer Society) and Lesson 19 on alcohol as a drug (Alcoholics Anonymous).

3. If you have not taught lessons on drugs before, it would be a good idea to discuss your plans on Lessons 19 and 20 with drug educators in your school or in your community.

4. Wherever possible, try to emphasize the relationship of the nervous system to the other body systems studied in Units I, II and III. This approach will help to give students a more holistic view of life.

LESSON 1: THE BRAIN: STRUCTURE AND FUNCTION

RATIONALE:

This is the first lesson of a sequence on the brain and its malfunctions. The sequence begins with an overview of the brain's functions. Since different functions are controlled by different parts of the brain, some of the experimental evidence that has led to an understanding of the brain's functional organization is presented. This is medically relevant, for impairment from strokes and other brain disorders can be understood from a knowledge of the functional organization of the brain.

OBJECTIVES:

The student will:

- state three important disorders of the nervous system.
- state one aspect of each of the following systems that is controlled by the brain: the respiratory, circulatory and digestive systems.
- state which parts of the body have the largest representation on the motor cortex and how this may be useful.
- state three functions of the hypothalamus and three functions of the medulla.
- locate the following structures in a dissected brain: cerebrum, the two hemispheres, cortex, cerebellum, brain stem, nerves, optic chiasm, gray matter, white matter, medulla.

SEQUENCE: ST-1; LA-1

SUGGESTIONS:

1. Much has been written on the vast and fascinating subject of the brain. The general physiology texts cited in the Introduction to the Unit in Unit III, Instructor's Manual, provide information. These include texts by Ganong and Vander. The following references on the brain may also provide some stimulation for interested students or background for yourself.

N. Calder, The Mind of Man, Viking Press, New York, 1970.

D. Kimura, "The Asymmetry of the Human Brain," Scientific American, 228, 70 (1973).

L. A. Stevens, Explorers of the Brain, Alfred A. Knopf, New York, 1971.

Altered States of Awareness, Readings from Scientific American, W. H. Freeman and Co., San Francisco, 1972. (This is a volume of reprints on dreaming and drugs.)

2. You may wish to relate some of the historical events that first pointed to the functional anatomy of the brain. See Information below.

3. You may wish to have students examine prepared slides of the brain or other nervous tissue. Slides may be obtained from most biological supply houses.

INFORMATION ON THE BRAIN:

1. The functional anatomy of the brain is of historical interest. Autopsies of people who died of African sleeping sickness revealed brains in which the hypothalamus was damaged. Today we know that some nervous tissue involved in sleep is located there. There is also the strange case of Phineas Gage, a railroad construction foreman who in 1848 had a four-foot iron rod blown through his head and lived. The rod destroyed a large part of his brain. After he recovered from the wound, his intellect was intact and he continued to practice his vocation.

This provides a dramatic historical illustration of the fact that an injury outside the motor and sensory cortex produces subtle rather than obvious changes. Many brain functions, such as learning, memory and thinking, are not confined to any specific part in the brain.

A famous experiment on rats also illustrates this point. Karl Lashley, an American neurophysiologist, trained rats and then removed specific parts of the brain to see which parts of the brain are associated with learned behavior. To his surprise, he found that the learning was retained as long as he left some part--any part--of the cortex intact. It didn't seem to matter which! Modern models of the brain attempt to explain this kind of experimental result. One model holds that information is duplicated throughout the brain, in many discrete places. Another model is that memory and thoughts are a function of the integrated action of many different parts of the brain. The immense number of interneuron connections could account for such interaction.

2. In the 1930's and 1940's prefrontal lobotomies were performed on severely ill psychiatric patients. Usually, in this operation the connections between the prefrontal lobes and the rest of the brain were cut.

At that time, the prefrontal lobes were believed to play an important role in thought associations. Since the mentally ill experience suffering related to their thought associations, it was hoped that disconnecting the prefrontal lobes would offer relief. It was used as an absolute last resort for people who could not be restrained from harming themselves or others.

The operation produced dramatic improvement in some, neutral effects in others, and negative results in still others. It was abandoned when the successful use of psychiatric drugs came about, for durgs involve no surgical risk. A lack of ordinary concern for others, observed in many who had undergone the operation, also encouraged its abandonment.

3. While much exploration has been done, much of the human brain still remains unexplored and even the areas explored contain much mystery. For example, the frontal lobes occupy one quarter of the volume of the cerebrum and yet their function, aside from some general role in personality, is largely unknown. The role of the brain in thinking and imagining is largely a mystery.

4. There is a laughter center in the thalamus. Accidentally discovered in 1955 during brain surgery, stimulation of it can make even a very ill or anxious patient smile or laugh out loud.

5. During brain surgery patients are normally conscious, for the brain itself has no nerve endings with which to register pain. Thus a local anesthetic for the scalp and skull is all that is used. The surgeon first stimulates a small region of the brain before cutting it. He observes the effect of the stimulation and asks the patient what he or she experiences in order to determine precise areas of the brain prior to cutting. Thus it is important for the patient to be conscious during brain surgery.

6. Much work has been done on the brain and dreaming. For instance, it is known that muscles throughout the body are ordered by the brain to relax during dreaming. One pioneer of dream studies has speculated that this acts as a safety feature to prevent us from acting out dreams and hurting ourselves. During dreaming the eyeballs, however, move rapidly. This is called "rapid eye movement" (or "REM") sleep.

7. While the conscious control of movements is the domain of the brain, some movements may be elicited from the spinal cord alone. This explains why chickens with their heads cut off may flop around.

INFORMATION ON LABORATORY ACTIVITY 1:

TEACHING NOTES:

1. The purpose of this activity is to allow students to see many of the important parts of the brain, including the blood vessels, and to develop manipulative

skills. Students will also observe nervous tissue microscopically.

2. Anticipated time: one period.

3. Preserved brains may be obtained from biological supply houses. Sheep, calf and pig brains are most suitable because of their relatively large size, but smaller brains such as rabbits' may be used, too. Fresh brains may be obtained from local butchers. If you elect to use fresh brains, make sure they are sold as individual brains. (Some butchers, especially those who work in large chain stores, sell them only in large frozen blocks made of many brains. These are damaged in processing and are not ideal for dissection. Smaller stores can sometimes order individual brains.)

Animal brains of various species are also available from Pel-Freez Bio-Animals, Inc., Box 68, Rogers, Arkansas 72756. They are shipped frozen. The company requires a minimum order of $26.50, plus transportation charges. $26.50 would purchase 46 rabbit brains.

4. You may wish to preserve fresh brains for future use. To do so, soak them in 10% formaldehyde (also called formalin) for a few days and then transfer them to 3% formaldehyde, in which the specimen will keep indefinitely. (A 3% formalin solution is less irritating to the eyes and skin than a 10% solution.) Formaldehyde is available in a concentration of 40%, which is diluted for laboratory use. Other embalming fluid concentrates are also available.

5. In the procedure, the steps marked with an asterisk involve dissection. These are Steps 5, 9 and 10. If an individual brain is to be used by more than one student team, you may wish to have each team perform the steps without asterisks before actually dissecting the brain. This permits each group to study an intact brain. After each team has studied the intact brain, the teams may perform the steps involving dissection. However, the amount of dissection is minimal and should not destroy any of the important structures.

6. A "practical" exam may be set up by sticking pins with numbered tags into different structures of the brain. Ask students to identify these structures. You might also ask students to state the symptoms and effects that would arise if one or more of these structures had its blood supply impaired by atherosclerosis, as in Part I, Step 20, of the activity.

7. Brains obtained from biological supply houses are superior to fresh ones because fresh brains sold as food may lack some structures, including the cerebellum, medulla, and pituitary gland. For this reason at least one wholly intact brain should be on hand. If you use fresh brains and the cerebellum, medulla and pituitary gland are missing, only the following steps in the procedure are applicable: Steps 1, 2, 7, 9 and 11.

The following list of structures generally visible in a fresh brain may also prove useful as a guide: the two hemispheres, the brain stem (the large mass of white matter on the base of the brain), the blood vessels, the olfactory bulbs (in beef brains, unlike sheep brains, these do not project out in front but are still identifiable by their white color). The place on the base where many blood vessels converge is also visible. The dissection steps students may perform on a fresh brain include cutting into a hemisphere to observe gray and white matter (the first paragraph of Step 10), and cutting between the two hemispheres (option 9a below).

8. You may wish to point out the role of the cerebral blood vessels in disease. Atherosclerosis of the arteries may lead to thrombosis and burst aneurism, conditions described in Unit III, Instructor's Manual, p. 47.

9. The following may be done as optional activities or as demonstrations.

a. Orient the brain so that the top side is facing up. Make a cut into the fissure between the two hemispheres, cutting all the way through to separate the hemispheres and then through the cerebellum and brain stem. Figure 1 on the following page shows such a cut surface in a human brain. The white tissue in the hemispheres which you cut is the corpus callosum, which is Latin for "calloused body." The corpus callosum is a mass of nerve cells that connects the right and left hemispheres. Through it, each hemisphere receives information from the other.

b. Make cross sections of the spinal cord 1 mm thick. White matter and gray matter in the spinal cord may be stained to reveal their classic structure: the "butterfly" of gray matter in the middle of the spinal cord, surrounded by white matter (Figure 2 below).

The stain is a 5% solution of aqueous silver nitrate. Soak the tissue until it darkens--about half an hour. Silver nitrate forms a dark precipitate with nerve tissue, particularly with the myelin in white matter. The white matter stains darker than the gray matter in this case. Cross-sections of the brain stem may also be stained. The "butterfly" of gray matter is not present in the brain stem, however. The gray matter there is arranged into a simpler, circular pattern.

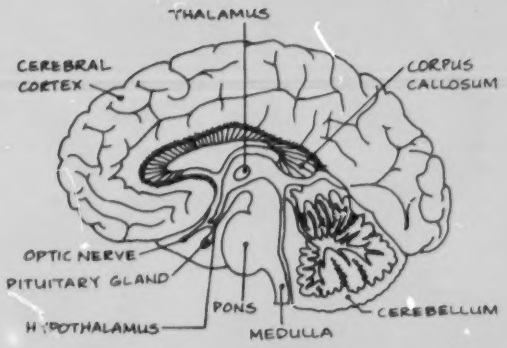


FIGURE 1: A section of the brain when cut on a plane between two hemispheres.

c. The brain contains hollow spaces. This may be demonstrated by slicing a brain from front to back, salami-fashion (Figure 3). There are hollow spaces (ventricles)

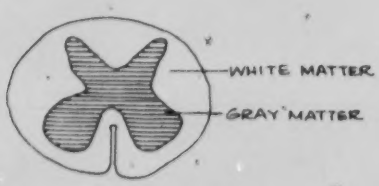


FIGURE 2: Stained cross-section of spinal cord, X3.

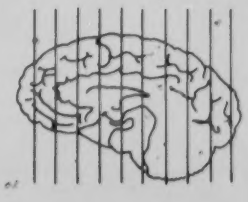


FIGURE 3: Side view of the brain showing lines for cutting to demonstrate its hollow structure.

in each slice. In life the hollow space is filled with cerebrospinal fluid, which flows into spaces between spinal cord membranes. Cerebrospinal fluid will be discussed in future lessons.

d. Nerves located in the brain may be removed and their cut ends examined microscopically using a wet mount. Students will see numerous axons in each nerve. White matter and gray matter in the brain may be similarly examined for the presence of axons (white matter) and cell bodies (gray matter).

MATERIALS: (for 10 set-ups)

- 10 brains, preserved or fresh
- 10 blunt dissecting probes
- 10 dissecting pans (or enough aluminum foil)
- 10 microscopes
- 20 microscope slides with cover slips
- 10 medicine droppers
- 10 scalpels or single-edged razor blades
- 0.5 g silver nitrate ($AgNO_3$) (optional)

PREPARATION OF REAGENT (OPTIONAL):

5% solution of aqueous silver nitrate: 0.5 ± .05 g silver + sufficient water to make 10 ± 1 ml.

ANSWERS TO PROCEDURE QUESTIONS:

1. No. The blood is very dark, sometimes black.
2. Beneath the membrane.
3. Yes.
4. No.

5. The cerebrum and cerebellum are connected by the brain stem.

6. Both contain "hills" and "valleys." The surface features of the cerebrum, however, are much larger than those of the cerebellum.

7. Less.

8. In the human a larger portion of the brain is taken up by the cerebrum.

9. Paralysis would be more likely to result from a blocked artery supplying the middle of the cerebrum.

KEY--STEP 19:

A. right hemisphere, hemisphere or cerebrum
B. optic chiasm
C. cerebellum
D. brain stem or medulla
E. olfactory bulb
F. nerves
G. spinal cord

KEY--STEP 20:

A-b, B-c, C-a, D-e, E-d, F-f

ANSWERS TO DISCUSSION QUESTIONS:

1. The number of cells in the brain is astronomical. Some anatomists estimate that there are about 10 billion neurons in the human brain.

2. The long axons serve to transmit electrical impulses from one part of the nervous system to another.

LESSON 2: (A) NEURONS AND THE TRANSMISSION OF IMPULSES

(B) ELECTRICAL IMPULSES IN NITELLA

RATIONALE:

The basic unit of the nervous system is the neuron. Many diseases involve abnormal discharges by neurons (as in epilepsy), degeneration of neurons (as in multiple sclerosis) or death of neurons (as in strokes and diabetes). ST-2 provides the background on neurons and the nervous system necessary to understand the lessons on nervous system disorders, sensory organs and drugs that follow. This lesson covers the structure and function of neurons. In the laboratory, students observe nerve-like impulses in a plant cell (Nitella).

OBJECTIVES:

The student will:

- identify the following structures on a diagram of a neuron: dendrites, axon, terminals.
- state the direction in which an impulse travels in neurons, in terms of dendrites and terminals.
- distinguish anatomically between the central nervous system and the peripheral nervous system.
- define the following terms: threshold, synapse, neurotransmitter, receptor.
- state how an impulse is transmitted from one neuron to the next.
- observe the transmission of electrical impulses in Nitella.

SEQUENCE: ST-2; LA-2

SUGGESTIONS:

1. The following activity may be of interest. Have the class hold hands in a line. Use a stopwatch or a clock. At the signal, the person at one end squeezes the hand of the next person, who squeezes the hand of the next person, etc., until the last person feels the squeeze and signals for the clock to be stopped. Do three runs and take the fastest time. Divide by the number of people in line to get the average transmission time per person. This measures the sum of the times for the following five events:

a. how long it takes the information that the hand has been squeezed (a set of nerve impulses) to go from the hand to the sensory areas of the brain.

b. how long it takes the brain to interpret the impulse.

c. how long it takes the motor cortex of the brain to give the order (another set of nerve impulses) to squeeze the next person's hand,

d. how long it takes the order to reach the hand, and

e. how long it takes the muscles of the hand to respond to the order.

2. The term neuron was used in Unit I, ST-17. The term was used to refer to the cells that composed Tommy's respiratory center and the pathways from the respiratory center to the muscles Tommy used in breathing. The respiratory center was shown to control the breathing rate. When Tommy plunged into icy water, the respiratory center responded initially by causing a temporary cessation of breathing. to the story to introduce neurons.

INFORMATION ON NEURONS AND NERVE IMPULSES:

1. There is a common misconception that the fluid outside of cell membranes is positively charged with respect to the fluid inside because the membrane forces out Na^+ ions. This is not the case; for every Na^+ ion it forces out, it forces in a K^+ ion, which by itself would maintain electrical neutrality. It is rather the greater tendency of K^+ ions to leak out than of Na^+ ions to leak in that causes the outside to be positive with respect to the inside.

2. Since impulses in all nerves appear to be similar, the question arises, "How do we perceive information from some nerves as touch and information from other nerves as hearing (or as movement, sight, etc.)?" The answer lies in the functional organization of the brain. All nerves conveying information on touch end in a part of the cortex different from where nerves carrying information on hearing end. In other words, a similar impulse will be interpreted in different ways by different parts of the brain.

3. Only 10 per cent of the nerve cells in the central nervous system are neurons. Ninety per cent are the "glue" cells of the nervous system, thought to maintain and hold the neurons together in some way. Their proper name is "glia," which is Latin for "glue." They do not conduct impulses, but some physiologists believe they influence neurons chemically.

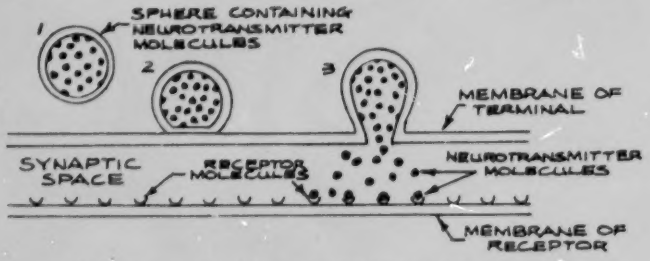
4. The axons of many neurons in the peripheral nervous system are wrapped by a thick layer of cell membrane rich in lipid. Such neurons are called "Schwann cells," and the thick membrane is called "myelin." Myelin is an excellent insulator. Cells that possess it transmit impulses faster than cells that do not.

5. It is possible for an impulse to move from terminal to dendrite. However, the dendrite-to-terminal direction is the usual one because a given neuron is usually stimulated by other neurons with synapses at its dendrites.

6. The dendrites of neurons are often covered with hundreds of terminals from other neurons. This is especially true in the brain. If enough of the terminals secrete neurotransmitter, they will make the neuron fire. (It usually takes more neurotransmitter than just one terminal secretes to make a neuron fire.) Thus, whether or not the neuron fires depends on the total "vote" of the group of neurons

that contact it. Some neurons, however, such as the ones involved in the "knee-jerk" reflex, fire when stimulated by a single neuron.

7. The figure below shows schematically the release of neurotransmitter molecules from spheres within the terminal. It is not known how the arrival of a nerve impulse at the end of a terminal causes neurotransmitter to be released. Once released it diffuses across the synaptic space and combines with receptor molecules in the membrane of the next neuron.

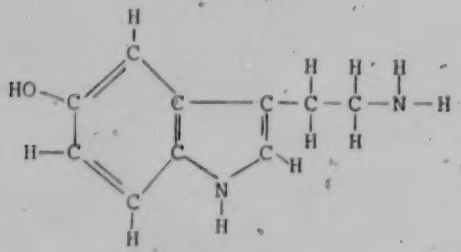


Release of neurotransmitter molecules from the terminal of a neuron to another cell.

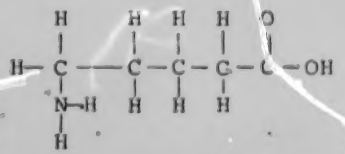
8. Some neurotransmitters stimulate a neuron to fire while others reduce this tendency. They have similar dual actions upon some glands, affecting their tendency to secrete, and upon gastrointestinal muscle tissue, affecting how much it contracts.

Neurotransmitters stimulate neurons by increasing the permeability of the neuron cell membrane to Na^+ ions, which move in, driving the membrane potential to threshold level. Neurotransmitters inhibit neurons by increasing the permeability to K^+ ions but not Na^+ ions. Thus K^+ ions diffuse out, and the potential goes further away from threshold.

9. The formulas for two of the most important neurotransmitters, norepinephrine and acetylcholine, are shown in the Instructor's Manual, Unit III, Lesson 7. They occur in both the peripheral and central nervous system. Other neurotransmitters include serotonin (5-hydroxytryptamine) and gamma-aminobutyric acid. The formulas are given below.



Serotonin



Gamma-aminobutyric acid

INFORMATION ON LABORATORY ACTIVITY 2:

TEACHING NOTES:

1. The purpose of this activity is to permit students to observe the propagation of electrical impulses in living cells.

2. Anticipated time: one to two periods.

3. Nitella is readily available from biological supply houses and may also be obtained from local pet shops, where it is sold as fish food and as an aquarium plant. This plant should be kept in indirect light at room temperature. In our experience, the plant will last for more than two weeks under these conditions.

4. Nitella cells should not be touched with metal because most metals (including BIP wire) stimulate the cells to produce impulses. However, nichrome wire may be used.

5. The 18-KΩ resistor is supplied with two short green connecting leads as a standard BIP accessory item. The resistors are also available from electronics stores. The resistors may be identified by their colored bands, which should be (in order) brown, gray, orange and silver (or gold).

6. It is best to prepare Nitella cells (Procedure Step 12) 30 minutes or more before stimulating them. This gives the cells a chance to recover from being handled.

7. It is desirable to display the impulse with an oscilloscope before beginning the activity so that the students can view the shape of the wave as it is produced on an oscilloscope. This optional procedure (Activity 2-A) is detailed following the Answers to Discussion Questions. Using this procedure, it is possible to demonstrate the impulse simultaneously with the BIP diode-light display and the oscilloscope. If extra oscilloscopes are available, the students are likely to enjoy performing the activity (2-A) more than watching a demonstration.

8. In the procedure, students are asked to set the mA dial 20 units higher than the null point of the diode lights. This setting is used because there is always some low-level electrical activity occurring in the plant, causing the diode lights to flip erratically back and forth. With the mA dial set above the null point, only those waves with heights (amplitudes) above a certain level will be picked up. This setting is therefore useful for displaying only the large waves that occur during the propagation of an impulse.

9. In our laboratory, we did not obtain a null point with some plants; in these cases, one diode light--the right one--always stayed on. If your students have this experience, tell them to treat the point at which the left diode light just goes on and off as the null point. This will create only a minor difference in the observations. Normally, when the impulse passes the first display electrode, the right diode light blinks on, and the left one blinks off. If the right diode light always stays on, the left one blinks on when the impulse passes.

10. To avoid confusion, you may wish to emphasize that the electrical current that stimulates the plant is not being conducted along the length of the Nitella cell. The electrical current passes only from S_1 to S_2, lasts only a fraction of a second, and serves only to touch off the plant's own response, which is an impulse conducted along its length. Other forms of stimulation besides electricity will produce this response. Step 18a gives students a chance to test other forms of stimulation. The brief burst of current is used in the activity because other stimuli last longer and produce more complicated responses in the Nitella cell.

11. On the oscilloscope, this set-up results in first an upward and then a downward deflection (LA-2, Figure 2). This is called a diphasic display. The classical picture of an impulse found in most physiology texts, however, shows a single deflection, called a monophasic display as shown in ST-2, Figure 5. This monophasic display results from introducing one electrode into the inside of a cell and placing the other outside. In this activity, on the other hand, both electrodes are on the outside of the cell. A deflection is produced as the impulse passes each electrode, as outlined in the Introduction to the activity. Therefore a double deflection--a diphasic display--is produced.

12. The following options may be of interest.

a. A stopwatch may be used to time the interval between the time of stimulation and the beginning of response. This can be divided into the distance between the nearest stimulating electrode and the first recording electrode (electrodes S_2 and D_1 in Figure 3 in the Procedure) to give the speed of propagation of impulse.

b. Observe Nitella with the microscope. Look for streaming: the movement of the cytoplasm. Large numbers of chloroplasts packed together can also be seen.

c. The common "sensitive plant," Mimosa, whose leaflets fold when touched, produces a large bioelectric response when it is stimulated. But Mimosa takes 10 to 20 minutes to recover after each impulse, so it is suitable only for demonstrations or student research projects.

To record a Mimosa impulse, fashion the ends of two electrodes into hooks about the diameter of the petiole or stem. To prevent artifacts due to unwanted movements, position one hook on the stem just below the angle of the petiole that is to be stimulated, and the other hook on the stem a cm or more above the soil. It might be necessary to ground the soil. There is no need to have stimulating electrodes--simply pass a source of heat, such as a burning match, quickly under the leaflets of one branch. The whole plant will be depolarized.

Mimosa is available at some plant stores, and seeds can be purchased through biological supply houses. Mimosa is easily sprouted from seeds. Remove the "paper" husk, nick the seed case and germinate the seeds for 24 to 36 hours on wet sand. The sprouts can then be planted in sandy soil. Use a high-humidity environment. The Mimosa plants should be ready in six weeks.

MATERIALS: (for 10 set-ups--not including options)

- Nitella for class of 50 [Carolina 15-1285]
- 10 Petri dishes, 100 x 15 mm
- 10 Petri dish bottoms, lids, or watch glasses
- thin cardboard sheet, about 20 x 20 cm, (for example, one manila folder will be enough for an entire class)
- 20 toothpicks
- 10 medicine droppers
- cellophane tape
- masking tape
- 5 to 10 thumbtacks
- 5 to 10 mm rulers
- 5 to 10 scissors, scalpels, or single-edged razor blades
- 20 feet of nichrome wire, 22-gauge
- 20 electrodes with shielded cables (thick wires with plugs)
- BIP wire, 60 feet
- 40 alligator clips
- 10 18-KΩ resistors with two leads attached
- 10 BIP's
- 10 wire cutter-strippers
- small screwdriver

ANTICIPATED RESULTS:

Depending upon the distance between the stimulating and the recording electrodes, the BIP will show a response in 1 to 5 seconds after electrical stimulation. In the response, the right diode light goes on and stays on for 1 to 3 seconds, while the left diode light goes off. This corresponds to the upward deflection of the oscilloscope trace (Procedure, Figure 2B). Frequently the light switches on and off twice in response to one stimulus, showing that two impulses have traveled down the length of the cell.

When the recording electrodes are reversed by switching the input jacks on the BIP, the right BIP light will go on during the downward deflection of the oscilloscope while the left diode light goes off (Procedure, Figure 2D).

Nitella is very sensitive to touch and readily produces impulses when touched.

When the two display electrodes are placed farther from each other, the light blinks on longer. If the students cut the Nitella between the two display electrodes (Step 18D), then the cut prevents the impulse from reaching the second electrode, so only a peak, but no valley, would appear on the oscilloscope. Students can detect the difference in the display on the BIP by reversing the input jacks at the BIP and seeing that no "valley" appears.

ANSWERS TO DISCUSSION QUESTIONS:

1. The right diode light displays the response of the plant: an electrical impulse passing the first display electrode (D_1) in the electrode stand.

2. Several answers are valid: the impulses are slower in Nitella, it is not necessary to kill an animal to obtain nerves and the cells are large.

3. Heat, mechanical (touch, pressure), light (stimulates neurons in the eye), motion (stimulates special receptors in the inner ears and muscles), sound (stimulates neurons in ear), chemicals (taste and smell).

LABORATORY ACTIVITY 2A: OSCILLOSCOPE DEMONSTRATION OF AN IMPULSE IN NITELLA

INTRODUCTION:

This demonstration enables an impulse in Nitella to be displayed simultaneously with the BIP diode-light display and with an oscilloscope.

MATERIALS: (per set-up)

oscilloscope plus materials for LA2 capacitor (if needed--see Step 5)

PROCEDURE:

1. Set up the plant as explained in LA-2.

2. In addition, connect BIP pin C to the vertical input of the oscilloscope.

3. Connect pin X to the oscilloscope ground terminal.

4. Plug in the oscilloscope. Switch it on and turn the intensity control high.

5. Use the oscilloscope as explained in Steps 5 through 9 in the Instructor's Manual, Unit III, pp. 40 to 41.

6. Stimulate the plant. The oscilloscope trace should first sweep up and then down, if the plant responds. If there is no oscilloscope response, check all wiring and if necessary use a different plant.

LESSON 3: EPILEPSY AND ELECTROENCEPHALOGRAPHY

RATIONALE:

ST-3 considers the disease epilepsy and the diagnostic tool, the electroencephalogram (EEG). Epilepsy is the first of several nervous-system disorders to be considered. These disorders and their signs and symptoms will be part of the computer-diagnosis sequence (Lessons 9 to 13). The condition was also chosen to illustrate the importance of the EEG in medicine. LA-3 allows the students to observe their own brain-wave patterns. It should be added that epilepsy is important to consider because it is one of the most common brain disorders in the United States.

OBJECTIVES:

The student will:

- list at least three factors that may contribute to an epileptic seizure.
- describe the activity of the brain neurons during a seizure.
- describe the appearance of normal and abnormal brain-wave patterns.
- state which waveforms are characteristic of a person who is awake, in deep sleep and in REM sleep.
- state how epilepsy is treated.
- demonstrate brain-wave patterns using a BIP.

SEQUENCE: ST-3; LA-3

SUGGESTIONS:

1. Students may be perplexed by the change in style of the case histories. The case history in Section 3-1 and others in this unit are written more in the style of a physician or other health professional. They are more terse and a little more technical than earlier histories to provide a more realistic account. The notes immediately following the case history provide some explanation of important details.

2. You may wish to reconsider the case history after completing a discussion of Section 3. By that time, the students should be able to understand the significance of most of the procedures and questions raised during the examination.

3. Additional information on epilepsy may be obtained by contacting organizations such as the Epilepsy Foundation of America, 5665 Los Virgines Road, Calabasas, California, 91302. If you live in a large city, check your phone directory for local groups.

4. Among the questions that may be brought up in the discussion of epilepsy is one about inheritance. That is: "Is epilepsy inheritable?" The answer is somewhat elusive. Clearly, many forms of epilepsy are not inheritable--for example, seizures may be due to a head injury or to a brain tumor. On the other hand, some forms of epilepsy appear to run in families. The precise relationship between genetics and epilepsy is not completely understood. At any rate, most physicans do not consider the genetic risk sufficient to warrant discouraging people with epilepsy against marriage or having children.

5. Students may raise questions about acquaintances who have had different kinds of epilepsy than the variety described in the case history. The case history was based on a real individual with idiopathic (meaning "of unknown cause") epilepsy. In this form of epilepsy there are no detectable neurological abnormalities except for the EEG pattern. And, in some cases, even the EEG appears normal. It should be emphasized that there are different forms of epilepsy. They have different causes (not all known), different characteristics and different brain-wave patterns. More information on the different forms of epilepsy follows these suggestions.

6. You could ask students to speculate on what should be done if they are present when a person has a seizure. (The main thing to do is to prevent the person having a seizure from hurting himself (or herself). The person should be moved to the floor or ground and turned on one side to help release saliva. If the person's mouth is open, a clean handkerchief can be placed between the teeth on one side of the mouth to prevent biting of the tongue. But the mouth should not be forced open. Upon recovery, if this is a first seizure, the person should be urged to contact a physican. In such a case, observations of the attack may be needed for the diagnosis.)

7. Students may be interested in learning about the kinds of drugs used in therapy for epilepsy. Some are sedatives--drugs that reduce the activity of the nervous system. More important are the anticonvulsive drugs, which differ slightly from sedatives and are more specific in their action. A more extensive treatment of drug therapy in epilepsy may be found in such pharmacology texts as L. S. Goodman and A. Gilman, "The Pharmacological Basis of Therapeutics," 4th edition, Macmillan Co., New York, 1970.

INFORMATION ON EPILEPSY:

Grand mal epilepsy

Grand mal means "great illness." It is the most prevalent and dramatic form of epilepsy. During a grand mal seizure, several things happen as described in the case history in ST-3. The patient may have a sense of an impending seizure. This is called an "aura." At first, breathing is suspended. During this phase, he may become blue (cyanotic), which may be quite alarming to the observer. However, this phase quickly passes following the resumption of breathing. Later the person's muscles become tense, his arms and legs extend and he falls or slumps unconscious to the ground. He may cry out and bite his tongue. When he resumes breathing and air returns to his lungs, the individual switches from rigidity to convulsions. Usually after about a minute, the convulsuions stop and the person returns to normality after a short period (1 to 10 minutes) of amnesia.

The earliest known account of a grand mal attack is the following one translated from the poet Lucretius, written in 95 BC:

"He foams, he groans, he trembles, and he faints;
Now rigid, now convulsed, his laboring lungs
Heave quick, and quivers each exhausted limb..."

Petit mal epilepsy

Petit mal means "little illness." In this form of epilepsy, the patient usually does not lose consciousness completely, but stops what he is doing and stares blankly as if day-dreaming. After a few seconds, he resumes what he was

doing. Such seizures tend to occur several times a day in patients. Petit mal epilepsy is generally a disease of childhood or adolescence. It is not as common in individuals over 20.

Jacksonian epilepsy

This kind of epileptic seizure is named after the discoverer, Hughlings Jackson. It is essentially a modified grand mal attack, but it begins differently. A Jacksonian seizure begins with a sensation such as a tingling or numbness in some area of the body. This is sometimes called a focal seizure. The attack then spreads from one set of muscles to another throughout most of the body. The patient may remain conscious during the early part of the attack and then black out as the attack spreads. Generalized convulsions often follow the spread of a Jacksonian attack.

Psychomotor epilepsy

In this less common form of epilepsy, there is a diminution or clouding of consciousness often triggered by a psychological disturbance, but the patient does not become unconscious. Such attacks may last a few seconds or minutes. Much less often, a psychomotor attack may last for hours or days. During a prolonged attack, a patient may behave in an unusual way. For example, it was presumably during such an attack that Vincent Van Gogh cut off one of his ears. Fortunately, most psychomotor seizures involve less dramatic effects.

INFORMATION ON LABORATORY ACTIVITY 3:

TEACHING NOTES:

1. The purpose of this activity is to demonstrate the electrical nature of the human brain and thus complement the treatment of this subject in ST-3. Electrical signals emanating from the brain are conducted (by means of electrodes placed on the scalp) to the BIP where they are amplified, and then displayed on an oscilloscope screen. This oscilloscope demonstration is analogous to the one described in the Instructor's Manual, Unit III, Lesson 8, for monitoring the electrical activity of the heart. You may wish to encourage students to review the earlier activity.

Following the demonstration, the students monitor their own brain waves using the diode lights of the BIP. This portion of the activity includes the monitoring of alpha waves, and this topic will be related to biofeedback in Lesson 4.

2. Anticipated time: one to two periods.

3. It is desirable to have a quiet, dimly lit room for this activity, particularly when the students are attempting to increase alpha activity. Perhaps the lights could be turned off once the initial programming, etc., has been accomplished.

4. The oscilloscope demonstration requires about 1/2 hour of pre-class preparation. (See the "Notes on Oscilloscope Demonstration" for details of the set-up.)

5. If extra oscilloscopes are available, you may wish to allow the students to connect them to the BIP as in the demonstration. This would help students to understand the significance of the diode-light changes.

6. Prior to the activity, the preamplifier gain control (the slotted control at the far right) should be adjusted to near maximum for each BIP. To do this, turn the slotted control clockwise as far as it will move freely. Then turn it back counterclockwise about one-eighth of a revolution.

7. Elastic bandages are available in 2-meter lengths at about $2.00 each. They may be cut into two pieces 1 meter long. The electrode with the unshielded lead may be secured to the arm with masking tape, if desired. If elastic bandages are unavailable, gauze, rags, etc. may be substituted.

8. If electrode paste is unavailable, a 5% solution of NaCl on absorbent cloth serves as an acceptable substitute. 200 ml of salt solution should be enough for one class.

9. The 18-ohm resistor specified in the Procedure is supplied with two short

green connecting leads as a standard BIP accessory item. The resistors are also available from electronics stores. They may be identified by their colored bands, which should be (in order) brown, gray, orange and silver (or gold).

10. The BIP is so designed that it is extremely unlikely that even a slight hazard could exist. If, however, any tingling is felt where the electrodes are attached (indicating a leakage of 0.1 to 1 mA of current), the subject should be disconnected immediately and the BIP should be checked (see Section 7 of the BIP Manual).

11. For good electrical contact, it is very important that the body surfaces where the electrodes will be placed be thoroughly cleaned. Since the back of the scalp is covered by hair, the placement of an electrode there requires special care. If the contact between this electrode and the scalp is poor, it may not be possible to obtain signals at all. Although this point is made in the procedure, you may wish to emphasize it before proceeding with the activity.

If you have access to an ohmmeter, it is possible to determine whether the contact of the scalp electrodes is satisfactory by measuring the resistance across them. This is done by securing the two scalp electrodes in position and connecting the ohmmeter to them. The resistance reading should be 10,000 ohms or less. Note: a high-resistance range setting should be used--a range in which the mid-scale reading is at least 10,000 ohms. If a lower scale setting were used, and the subject's skin resistance was quite low, then a small current (perhaps 1 mA) could pass through the scalp.

12. In both the demonstration and the student activity it is important that the BIP and oscilloscope be plugged into a grounded (three-pin) outlet to avoid picking up 60-cycle interference. If there is any doubt in your mind about the integrity of the grounds, you might have the school electrician check out the circuitry.

13. Demonstrating a high proportion of alpha activity generally takes some practice. It is possible that some students in the class will not be able to relax sufficiently in the test situation to show a predominance of alpha waves. There are, however, a number of techniques that aid people to produce more alpha activity. Two of these are listed below; you may wish to share them with the students.

a. Close your eyes. Imagine yourself going deep inside your body and concentrate on your breathing. Imagine that your body is a large container that you draw air into with each breath. As you breathe in, imagine the air flowing down into the bottom of the container, to your belly, and then gradually moving upward, filling your entire torso, all the way up to your neck. As you exhale, imagine air rushing gently out of the container, deflating it. Let your body go limp. As you continue to breathe, pause after each breath and wait until your body again feels the urge to breathe--do not make your body breathe, rather let it do so in a relaxed rhythmical manner. With each breath that you take, imagine all your muscles relaxing and your mind becoming quiet.

b. Close your eyes and concentrate on your breathing. Begin to breathe slowly and rhythmically. Now concentrate on your feet. Imagine that as you inhale, your feet expand (releasing all tension.) As you breathe out, feel the muscles relaxing. Now shift your concentration to your ankles and repeat the process there. Gradually move your attention up your body, from your ankles to your calves, knees, thighs, hips, abdomen, chest, shoulders, neck and head--then to your hands and up your arms. As you do this exercise, feel the wave of relaxation as it spreads throughout your entire body.

(Note: The above exercises are most effective when the instructions are given verbally using a slow, smooth delivery with no distractions. If you wish to use them, you might have each team connect up a subject and then give the instructions to all the subjects at one time. This procedure would have the additional benefit of reducing the amount of activity that is occurring in the classroom when subjects are attempting to increase alpha activity.)

MATERIALS: (for 10 set-ups)

- 10 BIP's
- 20 electrodes with shielded cables (and plugs)
- 10 electrodes with unshielded cables
- 10 resistors, 18K-ohm, 1/4 watt, attached to connecting wires

20 elastic bandages, 3 feet long

5 to 10 bottles of acetone (or soap and water)

cotton or cotton balls

2 tubes electrode paste (or 5% NaCl solution on absorbent cloth)

10 light shields (cloth or other appropriate material)

masking tape (or fasteners)

ADDITIONAL MATERIALS: (for optional demonstration)

oscilloscope

capacitor(s)

NOTES ON OSCILLOSCOPE DEMONSTRATION:

1. Connect the subject and the BIP as explained in Activity 3.

2. In addition, connect BIP pin C to the vertical input of the oscilloscope.

3. Connect pin X to the oscilloscope ground terminal.

4. Plug the BIP and the oscilloscope into grounded outlets, switch the oscilloscope on, and turn the intensity control high.

5. If there is a "60∿" switch on the scope control panel, make sure that you do not have it switched on. (The scope will not register a display with the "60∿" switch on.)

6. Adjust the horizontal- and vertical-position knobs until the display is roughly in the center of the screen. (The location and function of these knobs, and others mentioned below, were described in detail in Unit III, Lesson 8. Background information on the oscilloscope and how it works was also given in that lesson.)

7. Adjust the horizontal dimension of the display until it just fills the screen.

8. Adjust the vertical dimension of the display until it fills approximately half the vertical dimension of the screen.

9. Adjust the horizontal sweep of the oscilloscope to about three to four sweeps per second. You may need to attach a capacitor between the scope's external capacitor jack and the ground to do this. Try a 1.0 μF (microfarad) capacitor with at least a 100-V rating. (If the capacitor has a + and/or - at one or both ends, be sure the negative end is connected to the ground.) If you need a slower sweep try a larger-value capacitor or additonal capacitors in parallel with the first.

(Important: Any capacitor that is attached to the oscilloscope should be completely insulated with electrical insulating tape. A large voltage may build up across the capacitor and if accidentally contacted, a significant shock may result.)

10. At this point, brain electrical activity should be visible on the screen. If not, recheck all the connections carefully, and consult the list of technical difficulties that was included in the Instructor's Manual, Unit III, page 41. (If the height of the wave needs to be increased or decreased, adjust the preamplifier gain control to the desired level.)

11. The subject should be able to alter the oscilloscope tracing by clenching his teeth, blinking his eyes or swallowing. This is due to the electrical nature of muscle activity. Such movements should be avoided after Procedure Step 7 so that the display represents what is actually occurring in the brain and not artifacts.

12. If you wish to try to obtain a display of alpha activity on the oscilloscope first adjust the mA dial on the BIP as described in the activity. When an alpha wave is emitted, the lit diode will go out and the other diode will light up. The pattern that appears on the oscilloscope when this happens will be the alpha waveform.

ANTICIPATED RESULTS:

All students will be able to observe their brain electrical activity using the diode lights. They will also be able to observe the effect of muscle contraction (as in eye movements, swallowing, etc.) on the brain-wave display. It should be possible for some students to demonstrate a significant increase in the proportion of alpha waves.

ANSWERS TO DISCUSSION QUESTIONS:

1. Answers will vary. Some students should be capable of demonstrating an increased proportion of alpha waves as time passes and as they become more relaxed.

2. Answers will vary. They may include breathing techniques, visualization or imagery techniques, etc. Such "discoveries" should provide an interesting topic for class discussion.

3. Mathematical computations interfere with alpha-wave production.

LESSON 4: (A) BIOFEEDBACK TRAINING

(B) THE AUTONOMIC NERVOUS SYSTEM

RATIONALE:

Biofeedback training has recently been used in medicine for treatment of migraine headaches, hypertension, anxiety, muscle tension and other conditions. The technique holds much promise. The subject of biofeedback training fits well in a unit on the nervous system since most biofeedback responses involve the autonomic nervous system.

OBJECTIVES:

The student will:

- define biofeedback training and list at least two clinical applications of this technique.
- compare and contrast the central nervous system and the autonomic nervous system.
- state the advantages of having two opposing branches of the autonomic nervous system.
- determine whether a subject can alter brain waves, heart rate and skin temperature at will.

SEQUENCE: ST-4; LA-4

SUGGESTIONS:

1. You may wish to read more on the clinical uses of biofeedback training. However, the subject is not yet a common textbook topic. A good starting point for learning more about biofeedback is: B. B. Brown, New Mind, New Body, Bantam Books, New York, 1974. This book also includes an extensive bibliography.

2. Before students perform LA-4, you may wish to have them review the measurement of arteriolar pulse rate (Unit III, LA-5) and skin temperature (Unit I, LA-7).

3. The treatment of the autonomic nervous system is brief and you may wish to expand on the subject. To prepare for discussion of neural regulation of bodily processes, you may also wish to review examples of homeostatic regulation treated earlier in the course. A good example to reconsider might be heart-rate regulation (Unit III, Lesson 7).

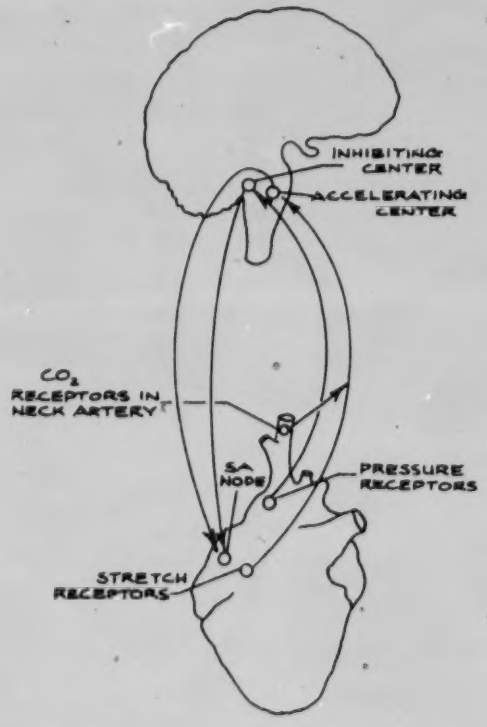
INFORMATION ON THE AUTONOMIC NERVOUS SYSTEM:

The autonomic nervous system (ANS) regulates many key internal processes. Neurons from the ANS innervate the heart and the smooth muscles in the walls of the digestive system, respiratory system, excretory system, blood vessels, etc.

One characteristic of the ANS is that a particular impulse in either branch of the system generally passes through <u>two</u> motor neurons. For example, in the sympathetic branch, an impulse begins in the cell body of a neuron in the middle of the spinal cord. This is a short neuron that synapses with a much longer neuron nearby, which goes to the target organ. Similarly, in the parasympathetic branch, there are generally two motor neurons that transmit each impulse. The cell body of the first motor neuron is in the brain or in the sacral region of the spinal cord. (See diagram in ST-4.) The first motor neuron is a long one, synapsing with a second, shorter motor neuron near the target organ.

Another important characteristic of the ANS is that its two branches (the sympathetic and parasympathetic nervous systems) are generally antagonistic in action. As an example of how the two branches of the ANS oppose each other, consider the neural control of heart rate. This example also stresses the interaction of the central nervous system and ANS. Recall that the heartbeat is initiated by the SA node in the heart wall. Although the SA node fires independently (does not require outside stimulation), its rate is controlled by two sets of nerves. The sympathetic neurons are excitatory; they speed heart rate. The parasympathetic neurons are inhibitory; they slow heart rate.

The sympathetic motor neurons that excite the SA node originate in the spinal cord. (In Unit III, we referred to these neurons as the "accelerator" nerves.) However, the impulses that these neurons transmit begin not in the spinal cord, but in an "accelerating center" in the medulla of the brain (see figure). Similarly, the parasympathetic neurons--the vagus nerves referred to in Unit III--carry impulses that begin in the "inhibiting center" of the medulla. (The word "vagus" means "wandering" in Latin. This nerve has this name because it has branches that go not only to the heart, but also to several other organs.)



Several kinds of signals can cause the accelerating center in the medulla to send an impulse to the SA node and thus increase the heart rate. One kind comes from a stretch receptor in the wall of the heart. The stretch receptor responds when the right atrium is expanded by a large volume of blood. When this happens, an impulse goes from the receptor in the right atrium to the accelerating center in the medulla. The accelerating center then sends an impulse to the spinal cord and from there to the heart. The accelerating center in the medulla may also excite the SA node in response to other signals such as impulses from arteries in the neck. These, in turn, are stimulated by high blood CO_2 concentration. Most of the factors that trigger the sympathetic neurons to make the heart beat faster result from stress or exercise.

As the heart rate increases, the blood pressure goes up. Pressure receptors in the aorta detect this increase and send impulses to the inhibiting center in the medulla. The inhibiting center then sends impulses via the vagus nerve to the SA node to slow the heart down.

Basically, the relative activity of the accelerating and inhibitory centers of the medulla determines the heart rate at any given instant. Thus the ANS plays a

key role in homeostasis in this system. Hormones, mainly from the thyroid gland, also help to regulate the heart rate.

INFORMATION ON LABORATORY ACTIVITY 4:

TEACHING NOTES:

1. The purpose of this activity is to give the students an opportunity to experience some of the techniques used in biofeedback training. The three physiological variables that were chosen are among those used in clinics where biofeedback training is done.

2. Anticipated time: two to four periods.

3. By the time the students undertake this activity, they should have been exposed to all the techniques involved. However, you may wish to review the arteriolar pulse rate technique (Unit III, Lesson 5) and the thermistor techniques in Unit I, Lesson 7.

4. The stations should be set up ahead of time. It would be desirable to have more than one of each of the stations. This may not be possible for the alpha-wave station since each station requires an oscilloscope. However, there should be no problem with setting up two or three of each of the other stations.

5. Stations should be set up as far apart as possible, so that the activity at one station will not distract the team using another one. If at all possible, it would be preferable to have the alpha-wave set-up(s) in a separate room.

6. The set-up for monitoring alpha waves requires a special electronic filter. This filter has been designed in such a way that it allows waves of a frequency of 9 cycles per second to pass through relatively unimpeded. Waves of lower and higher frequencies will be decreased in amplitude as follows. A wave with a frequency 7 or 11 cycles per second will have its amplitude decreased by a factor of 2; waves of frequency 5 or 13 cycles per second will have their amplitudes decreased by a factor of 4, etc. In this manner, all activity except that centered around 9 cycles per second will be greatly reduced. (However, alpha waves will vary in amplitude.) Thus beta activity will show up on the oscilloscope screen as waves of very small amplitude, and whenever alpha waves are present, waves of much larger amplitude will be noted.

This filter may be obtained as an optional BIP accessory. Attach the filter card to the BIP and oscilloscope as follows. Unplug the BIP and disconnect the wire between the BIP and the vertical input. Connect terminals Y and Z on the back panel of the BIP to connecting pins with the same letters on the filter. Connect terminal V or X of the BIP to connecting pin I on the filter card. Connect pin 0 on the filter card to the vertical input of the oscilloscope. Plug in the BIP..

7. It is not expected that most students will demonstrate dramatic changes in physiological processes that they are measuring for in this activity. It takes much time and practice to become proficient in control of the processes being investigated. The object of the activity is to introduce the techniques.

8. If any of your students are particularly interested in practicing these techniques you may wish to make the equipment available to them at other times.

9. Directions for connecting the oscilloscope to the BIP were provided in Lesson 3. Note that the Procedure assumes that you will be adjusting the oscilloscope. Once the set-up is operating properly, you may prefer to show the students how to adjust the display.

MATERIALS: (for three stations, one of each type)

light source	
photocell and associated circuitry (see p. 18, Unit III, Instructor's Manual)	heart rate
ring stand and 2 clamps	

2 electrodes with shielded leads
electrode with unshielded lead
18K-ohm resistor, soldered into BIP wire
alpha filter
2 elastic bandages (1-meter length each), with 2 clips
electrode paste
acetone
absorbent cotton
light shield (cloth, etc.)

} alpha-waves

thermistor component
cotton
tape

} skin temperature

3 clocks or watches wih second hand
3 BIP's
oscilloscope

ANTICIPATED RESULTS:

The results will vary with individual students. It should be possible for many students to demonstrate at least some change of their brain-wave patterns, skin temperature and heart rate.

ANSWERS TO DISCUSSION QUESTIONS:

1. Some students may be able to increase their alpha waves production. Conditions that favor this are quiet, dark, relaxation, lack of distractions. Conditions that usually inhibit production of alpha activity are distractions, mental activity of the problem-solving variety, physical discomfort, etc.

2. If there are students in the class who meditate regularly, they may be able to produce alpha-wave activity more freely than others. This is true because meditation usually leads to a state of deep relaxation and this type of state is helpful in the production of alpha-wave activity.

3. Some students may be able to increase the temperature of their hands. This technique is used in medicine to divert blood flow from the brain and has been used successfully in prevention and treatment of migraine headaches. Of course, the general technique of learning to divert blood flow from a specific area of the body might have many uses in medicine, such as control of bleeding.

4. Answers will vary.

5. Answers will vary. At the present time, other functions such as muscle contraction and blood pressure are being investigated. However, research on controlling such factors as permeability of cell membranes is already more than just a thought in the minds of some investigators. We are only just beginning to discover the functions to which biofeedback training may be applied.

LESSON 5: (A) REFLEXES

(B) MULTIPLE SCLEROSIS

RATIONALE:

Reflexes, the major subject of this lesson, are important automatic responses controlled by the nervous system. Abnormal reflexes indicate nervous-system defects and are therefore important in diagnosis. The clinical importance of reflex testing is illustrated in ST-5 with regard to multiple sclerosis (MS). MS also will serve as one of the disorders in the computer diagnosis activities (Lessons 9 to 13). In LA-5 the students will use a series of standard clinical methods to test reflexes.

OBJECTIVES:

The student will:

- describe the nature and symptoms of multiple sclerosis.
- list at least three examples of reflex action.
- give at least two reasons why reflexes are important.
- give an example of a reflex arc and explain how it functions.
- explain how the brain typically controls a reflex mechanism.

SEQUENCE: ST-5; LA-5

SUGGESTIONS:

1. The case history raises difficult ethical questions that students may wish to discuss. In the story the physician discovers evidence suggesting a very serious, slowly developing neurological disease--multiple sclerosis. Thorough testing suggests, but does not prove, that the patient has MS. The physician can offer no cure and the patient is in remission at the end of the story. The physician decides not to tell the patient at this time that she may have MS. Perhaps the physician fears that the patient may have a severe emotional setback if told the truth. At any rate, it would be good to let students vent their opinions about the case. Note that Biomedical Social Science Unit IV includes a supplementary lesson on "The Doctor's Dilemma" in this case history. You should arrange with the Social Science instructor to use that lesson soon after you have taught this one.

2. The finding of high gamma globulin levels in the spinal fluid of most MS patients suggests that this disorder may be related to the immune system. There is, therefore, an opportunity to reinforce the earlier treatment of immunology (Unit III, Lessons 14 and 15) at this time. Two hypotheses about the cause of MS that have been suggested by researchers are (1) that MS may be an autoimmune disease and (2) that MS may be caused by an elusive virus.

3. It might be effective to demonstrate a few reflexes before considering how they work. You may find the reflexes discussed in ST-5 or LA-5 of use for this purpose. You could also tape record several sounds and ask the students to describe their responses (reflex actions). Sounds that might evoke notable reflex actions include a police whistle, a telephone ring, a scream, scratchy chalk. Another kind of reflex that could be elicited is a sneeze caused by smelling pepper.

4. An important point that students may miss on casual reading of ST-5 is that for every reflex, there is a cause (stimulus) and effect (reflex). You might discuss some reflexes and have students tabulate the stimulus and response as indicated on the following page for each of the four examples given in Section 5-2.

Situation	Stimulus (Cause)	Reflex (Effect)
Loud dinner call	Noise	Eyes blink, head jerks
Person smells pizza	Odor	Salivation
Piece of pizza enters trachea	Tactile (particle contacts trachea wall)	Coughing
Knee-jerk reflex	Tapping	Leg straightens, foot kicks out

5. Another important point about reflexes to emphasize is that a reflex response occurs without our consciously perceiving the stimulus or directing the response. For a stimulus to be consciously sensed, a neural impulse must reach the brain; but many reflexes involve the spinal column and do not necessarily involve the brain. This point can be explained by examples. For instance, if a student accidentally touches a hot surface such as a stove, he will pull his hand away from the surface even before he realizes that he has touched something hot. True, the nerve impulse will reach his brain shortly after reaching the spinal cord, but by the time the brain responds, the protective reflex will already be in motion.

6. That a reflex action is independent of the brain is stated without proof in ST-5. Skeptical students may want evidence that the brain does not govern responses in a reflex action. Many fascinating experiments have provided much evidence. One is described in the information following these suggestions. You may wish to discuss the experiment with your students.

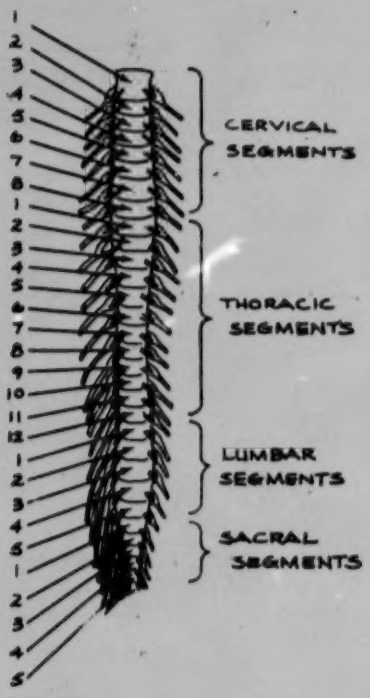
7. In Section 5-2, the knee-jerk reflex is used to illustrate a reflex arc. This is a very popular, "classic example" of a reflex, yet it is not a typical reflex. The knee-jerk reflex was chosen because the reflex arc is anatomically simple, because the reflex action is likely to be familiar to students and because the reflex has medical importance as a diagnostic indicator.

You may wish to explain to students that a reflex arc is usually more complicated than shown. For example, several neurons (not just two) generally compose a reflex arc. Also, in a reflex, one muscle (or body part) may be stimulated and another muscle (or body part) may respond.

8. A point that should be stressed, particularly in relation to LA-5, is that different reflexes generally involve different nerves. Thus an abnormal reflex in a clinical test indicates that a particular nerve or group of nerves is damaged.

The figure below shows how the vertebrae and nerves in the spinal cord are numbered. To illustrate the diagnostic value of reflex tests with regard to LA-5, you may wish to indicate the following relationships.

Reflex	Relevant Nerves
Quadriceps	Lumbar 2, 3 and 4
Hamstring muscle	Sacral 1 and 2
Biceps	Cervical 5 and 6
Triceps	Cervical 6, 7 and 8
Brachioradialis	Cervical 5 and 6



Background Information: An Early Experiment on Reflexes in Mammals

Among the many pioneers in neurophysiology, Nobel Laureate Charles S. Sherrington stands out. Sherrington demonstrated in the late 19th century that when the brain (cerebrum) of a dog is removed the "decerebrate," or "brainless," dog can continue to live for several days. This was no simple feat: scientists who had earlier attempted to remove the cerebra of mammals had lost their "patients" almost immediately after surgery due to massive hemorrhaging. Sherrington found that he could save the dogs by quickly and carefully sealing off certain arteries and using blood-clotting agents. But the significance of Sherrington's studies was far more than a surgical breakthrough. Sherrington's brainless dogs were an ideal system with which to test whether reflex actions could occur in the absence of a brain.

Most people have seen dogs scratch themselves to relieve an itch. Sherrington wondered whether this kind of reflex could be demonstrated in decerebrated dogs. To answer this question, Sherrington created an "imitation flea." The imitation flea consisted of a pin that conducted a weak electric current. A momentary, miniscule electric shock simulated a flea bite. Sherrington discovered that the brainless dog responded to the imitation flea bite precisely in the same way as any normal dog with an intact brain. In either case, the dog would lift a leg and scratch its fur rhythmically. Though Sherrington's experiment may sound frivolous, it led to much other research and a great deal of knowledge regarding the mechanisms of reflex actions. In particular, his experiments on decrebrate dogs proved that a reflex action could be independent of the brain.

INFORMATION ON LABORATORY ACTIVITY 5:

TEACHING NOTES:

1. The purpose of the activity is to demonstrate some body reflexes of clinical importance.

2. Anticipated time: one period.

3. You may wish to stress that the reflexes may be tested in any sequence. If there is a shortage of reflex hammers or penlights, you can get along with fewer with students working at different stations. For example, 1 or 2 penlights could suffice.

4. Eliciting reflexes can be a chancy business for the inexperienced. If a student is unsuccessful in producing a reflex after a few tries, he should record his lack of success rather than continue to harass his partner.

5. Failure to elicit a response is likely to be due to striking the wrong place. You may wish to review the names of muscles, tendons and bones cited in this activity. Most human physiology textbooks will have suitable diagrams and pictures that may be used for this purpose.

6. You might consider inviting a nurse-practitioner or physician to visit your class during this activity to demonstrate proper techniques for eliciting reflexes.

7. Three reflexes tested for in this activity are often referred to by other names. The following table provides the equivalent terms.

REFLEX	ALSO CALLED
Quadriceps (knee jerk)	Patellar
Hamstring muscle (ankle jerk)	Achilles reflex
Pupil	Pupillary light

8. Students should certainly try to elicit reflexes on both sides of the subject's body, but they should be cautioned to draw no inferences about nerve functions if different results are obtained. Any differences found will, in all probability, be a result of faulty technique.

9. For the blink reflex, students might use Plexiglass, acetate or other hard transparent plastic sheets. Another possibility would be for the subject to wear safety goggles.

10. Directions for making a simple reflex hammer are provided below. You might also be able to borrow a few reflex hammers.

11. Note that the reflex hammer is designed with <u>two</u> rubberized surfaces. Physicians use the pointed edge for some reflexes and the wide edge for others. You may wish to allow your students to test the effects of the two surfaces on the same reflex. With novices, however, it is probable that the broader surface will be more effective since it offers a greater chance of striking the correct spot.

<u>MATERIALS</u>: (for 15 set-ups)

15 reflex hammers

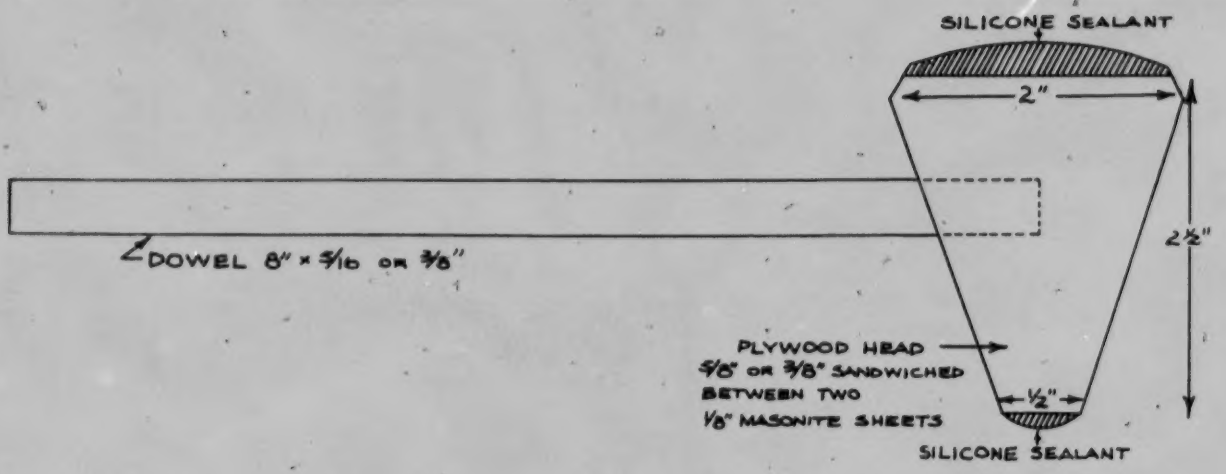
15 penlights (or other small flashlights)

15 clear stiff plastic sheets, at least 15 x 15 cm

15 pencils with eraser tips

<u>PREPARATION OF A REFLEX HAMMER</u>:

An inexpensive reflex hammer for student use may be prepared as indicated in the diagram on the following page. The silicone sealant on both sides of the hammer provides a rubbery surface and is a necessary safety factor. Allow about 24 hours for the silicone sealant to cure. The 1/8" Masonite on opposite sides of the hammer head adds weight to make the hammer more effective. The Masonite may be glued onto the plywood.



ANTICIPATED RESULTS:

I. The quadriceps reflex throws the calf forward. The leg straightens out. The reflex is augmented by pulling the arms in opposite directions as indicated in the procedure.

II. The hamstring reflex may not occur without some tensing of the muscle. It throws the toe of foot downward.

III. The biceps reflex causes the forearm to jerk upward. (Many students have difficulty eliciting the biceps and triceps reflexes. It may be helpful to observe the muscles and watch for contraction or bulging.)

IV. The triceps reflex causes a jerk in the rear of the upper arm. It may also be possible to observe muscle contraction and a straightening of the arm.

V. The brachioradialis reflex causes the hand to jerk upward and rotate.

VI. Light shone into an eye causes the pupil to constrict. The other pupil constricts similarly. The same reflex occurs when the focus of the eye is changed from far to near.

VII. The blink reflex usually occurs in both eyes. The reflex generally ceases after about 4 to 6 trials.

ANSWERS TO DISCUSSION QUESTIONS:

1. The easier reflexes for the beginner to observe are I, II, VI and VII. The other reflexes are likely to be harder for novices to elicit.

2. Conditions that increase the reflex action: relaxed subject, striking the precise spot (in Parts I through V), use of a sharp blow with the right amount of force. Conditions that decrease the reflex action: tensed subject, improper technique.

3. By concentrating thought away from the quadriceps muscle, the subject will tend to relax the quadriceps muscle.

4. Uneven responses are likely to occur in tests performed by novices because of improper technique.

LESSON 6: CEREBRAL HEMORRHAGE AND HEAD INJURIES

RATIONALE:

This lesson continues a presentation of clinically important nervous-system disorders. The emphasis on diagnosis of brain disorders continues because this information will be used in the computer-diagnosis sequence (Lessons 9-13). In LA-6, the students examine simulated cerebrospinal fluid (CSF), since analysis of CSF provides clues to the presence of cerebral hemorrhage (and other nervous-system disorders).

OBJECTIVES:

The student will:

- list at least two functions of CSF.
- list three substances analyzed for in CSF and state the significance of the presence of each of these substances.
- state the most common cause of cerebral hemorrhage.
- list at least two possible health problems besides cerebral hemorrhage associated with major head injuries.
- analyze simulated CSF for red blood cells, globulin concentration and total protein concentration.

SEQUENCE: ST-6; LA-6

SUGGESTIONS:

1. In the process of discussing this and the following two lessons, it would be useful to stress the diagnosis of each disease that will be part of the computer-diagnosis sequence (Lessons 9-13). The relevant diseases are brain tumor, cerebral hemorrhage, cerebral thrombosis, epilepsy and multiple sclerosis.

2. One reason head injuries were included in this lesson is that accidents leading to head injury are relatively common among high-school students. In this age group, more people die from accidents than from any other single cause. In a typical high-school class, it is likely that at least one student will have suffered a moderate or severe head injury.

3. The complete case history at the end of the section is written on a professional level with specialized vocabulary that will be new to the students. It is intended as supplementary material and may be used in different ways, as suggested below.

a. If you are short on time or if you feel the treatment of the case history is too sophisticated for your students, you may omit the supplement. The material in the supplement is not required to meet the objectives of this lesson and is not required for later lessons.

b. You could assign the supplement as a student library research problem. Ask students to figure out the significance of the comments of the physician in the case history.

c. You could use the case history as a vehicle for a review of topics considered in earlier lessons. The topics touched on and ties to earlier lessons are summarized below.

(1) diet and hypertension--Unit II, Lesson 21; Unit III, Lesson 6

(2) obesity and hypertension--Unit II, Lesson 33

Note: There is a significant positive correlation between obesity and cerebral hemorrhage. Cerebral hemorrhage is more common among obese people than among people of normal weight.

(3) Thiazide (a diuretic) and heart disease--Unit III, Lesson 12

(4) hypertension and heart disease--Unit III, Lesson 6

(5) aldósterone and water retention--Unit III, Lesson 20

Note: When Thiazide therapy failed, the patient was switched to Aldomet, a drug that suppresses the production and release of aldosterone in the blood.

(6) body sounds--Unit III, Lesson 5

Note: A comatose individual may have difficulty clearing secretions efficiently from the bronchial tree. This difficulty is dangerous because it can lead to complications such as pneumonia. In the case history the detection of tracheal rales (abnormal sounds) indicates a failure to clear the bronchial passages properly.

(7) atherosclerosis and heart disease--Unit II, Lesson 13; Unit III, Lesson 9

Note: The clue to atherosclerosis in the case history is that the patient had a diminished blood flow through the blood vessels in his feet.

(8) reflexes--Unit IV, Lesson 5

Note: The Babinski or plantar reflex was described in ST-5.

4. A few other features of the case history may not be obvious and may deserve consideration.

a. There are a few references to studying the blood vessels in the eyes. The veins and arteries of the eye can be seen with an ophthalmoscope. In a hypertensive patient, the arteries appear much smaller than the veins, and the arterial pathways are more tortuous than normal. An ophthalmoscope can also be used to examine the optic disk or optic fundus, which is the spot at which the optic nerves leave the back of the eyeball. In a patient with abnormally high intracranial pressure, the optic nerves are squeezed and their ends protrude into the eyeballs. This change causes the optic disks to appear blurred when viewed through an ophthalmoscope. Note: Lesson 8 includes further information about the use of eye examinations to diagnose brain disorders.

b. There is a reference to "grade 2 hypertensive changes." Physicians use a grading scale to indicate the severity of hypertension. The scale runs from 1 (for the least change) to 4 (for the most). "Grade 2" indicates significant but not very severe hypertensive change.

c. The case history refers to "vital signs." The three most important of these are respiration rate, blood pressure and heart rate.

d. "CVA" is the abbreviation for "cerebrovascular accident." It is the technical term for "stroke." If the effect of the accident is sudden, it is likely to be due to cerebral hemorrhage as in the case history. If the effect is more gradual, it is likely to be due to cerebral thrombosis, the subject of the following lesson. The more serious of the two is generally cerebral hemorrhage.

e. When a patient is discharged from a hospital, the hospital records will contain the information mentioned in Note 4 after the case history. On the first page of such a record will be a list of conditions treated and the status of the patient at the time of discharge with regard to each condition. In this case history the first condition listed would be cerebral hemorrhage, the second would probably be hypertensive vascular disease, and so on.

5. You may wish to mention the disease meningitis. Students who have heard of this disease may recognize that it must have something to do with the meninges. As the name suggests, meningitis is an inflammation of the meninges. Meningitis is a brain disease of considerable importance: it is approximately the sixth leading cause of death in children in the age range of 1 to 14 years.

There are several forms of meningitis, the most common resulting from bacterial

infection. Such an infection is often caused by a punctured eardrum. It is important to diagnose bacterial meningitis as quickly as possible. If diagnosed early enough, the disease can generally be treated effectively with antibiotics. Students may be interested to know that the CSF provides key clues in diagnosis of this disease. The CSF of patients with this disease is typically at a high pressure, contains bacteria and shows a high protein concentration. Microbiological testing often suggests the best method of treatment.

INFORMATION ON LABORATORY ACTIVITY 6:

TEACHING NOTES:

1. The purpose of this activity is to acquaint the students with techniques for discovering abnormalities in CSF. Students examine CSF samples for the presence of red blood cells, increased total protein levels and increased gamma globulin levels. Clinical problems that involve CSF analysis include cerebral hemorrhage, multiple sclerosis, cerebral thrombosis, brain and spinal tumors, meningitis, poliomyelitis and neurosyphilis.

2. Anticipated time: two periods.

3. It is likely that the students will require instruction in the use of the centrifuge. It is recommended that you demonstrate proper use of the centrifuge prior to beginning the activity. Common errors made by beginners when using a centrifuge include the following.

a. Failure to Secure the Centrifuge in Position: (Some centrifuges tend to "walk" if not properly secured. These centrifuges generally have rubbercup feet which should be moistened with water before tubes are placed in the centrifuge.)

b. Failure to Balance the Tubes: (This may cause damage to the centrifuge. You may wish to emphasize that pairs of tubes should be placed opposite each other and that opposing tubes should have approximately the same volume, i.e., ± 0.2 ml. For most centrifuges it is not necessary to balance the tubes by weight exactly. The major exceptions are ultracentrifuges.)

c. Failure to Attain Speed Properly: (Some centrifuges may blow a fuse if switched to full speed immediately. The speed should be increased to maximum gradually.)

d. Failure to Allow Centrifuge to Come to a Smooth Stop: (Occasionally students waiting for the centrifuge to stop try to rush things by damping the spinning centrifuge with their hands. This should be discouraged; it can cause the sediment to mix with the supernatant.)

e. Failure to Keep the Supernatant and Sediment Separate: (Jolting of the centrifuge tubes in the process of moving them can resuspend the sediment.)

4. You may wish to emphasize that Parts I, II and III of the activity may be completed in any order. This may help prevent bottlenecks due to insufficient centrifuges or BIP's.

5. If no centrifuge is available, the students (or you) may pipet test-tube samples of each of the simulated cerebrospinal fluids and allow them to settle overnight (or at least four hours) in the refrigerator.

6. The procedure calls for four simulated cerebrospinal fluids in containers labeled "A," "B," "C" and "D." These may be a normal fluid, one with blood, one with high protein and one with high gamma globulin. But alternatively, you may wish to complicate the task by preparing one sample with two abnormalities. For further information, see Preparation of Reagents.

7. The test for gamma globulin takes advantage of the different solubilities of gamma globulin and albumin in ammonium sulfate solutions. Gamma globulin typically precipitates in a solution that is 20% ammonium sulfate, while albumin normally precipitates only when the ammonium sulfate concentration is above 40 or 50%. When equal volumes of CSF and gamma globulin reagent are mixed (as in the procedure), the concentration of ammonium sulfate is about 25%.

8. The materials list assumes that the students will work in groups of three. You may wish to direct the students to work alone or in pairs. If you take this option, you will need to adjust the amounts of materials and to instruct the groups to share items that are in short supply, such as BIP's, centrifuges and microscopes.

MATERIALS: (for 10 set-ups)

- fresh egg (any size)
- 11 g sodium chloride (NaCl)
- 250 mg bovine gamma globulin (Sigma BG-II)
- 10 g sulfosalicylic acid [$C_6H_3(OH)(SO_3H)(COOH)\cdot 2H_2O$ or anhydrous form]
- 140 g ammonium sulfate [$(NH_4)_2SO_4$]
- 1 drop fresh blood
- sterile lancet and alcohol cotton wipe packet for obtaining blood
- 10 microscopes
- 20 microscope slides
- 20 cover slips
- 40 medicine droppers
- 1 to 4 centrifuges
- 20 to 40 centrifuge tubes
- 4 flasks, 250-ml (for spinal fluid specimens)
- 90 test tubes, 16 x 125 mm, Pyrex
- 50 pipets, 10-ml
- 10 pipets, 1-ml
- 10 test-tube racks
- 10 glass-marking pencils
- Parafilm
- 10 BIP colorimeters

PREPARATION OF REAGENTS: Note that a flow chart is provided for the preparation of the simulated cerebrospinal fluids.

Saline Solution: Dissolve in 1250 ± 10 ml water, 11.0 ± 0.5 g NaCl.

Simulated Normal CSF: Mix gently for several minutes 1000 + 10 ml saline solution and 3.0 ± 0.5 g egg albumen (30 ± 5 ml from fresh egg white). [A small syringe is especially useful for transferring and measuring (weighing) egg white.] Save 250 ml of this solution for the normal spinal fluid. The remaining 750 ml will be used for the spinal fluids containing high protein and blood. The solution may be stored in a refrigerator for up to a week.

Simulated CSF with Blood: Mix 1 drop fresh blood (as from finger prick) with 500 ± 10 ml simulated normal spinal fluid. This solution may be stored up to a week under refrigeration. Since the red cells settle, stir before using in the laboratory activity. Only 250 ml of this solution is needed; the rest may be discarded.

Simulated CSF with High Protein: Mix 1.75 ± 0.1 g egg albumen (from fresh egg white) with 250 ± 5 ml simulated normal spinal fluid. The solution may be stored in a refrigerator for up to one week.

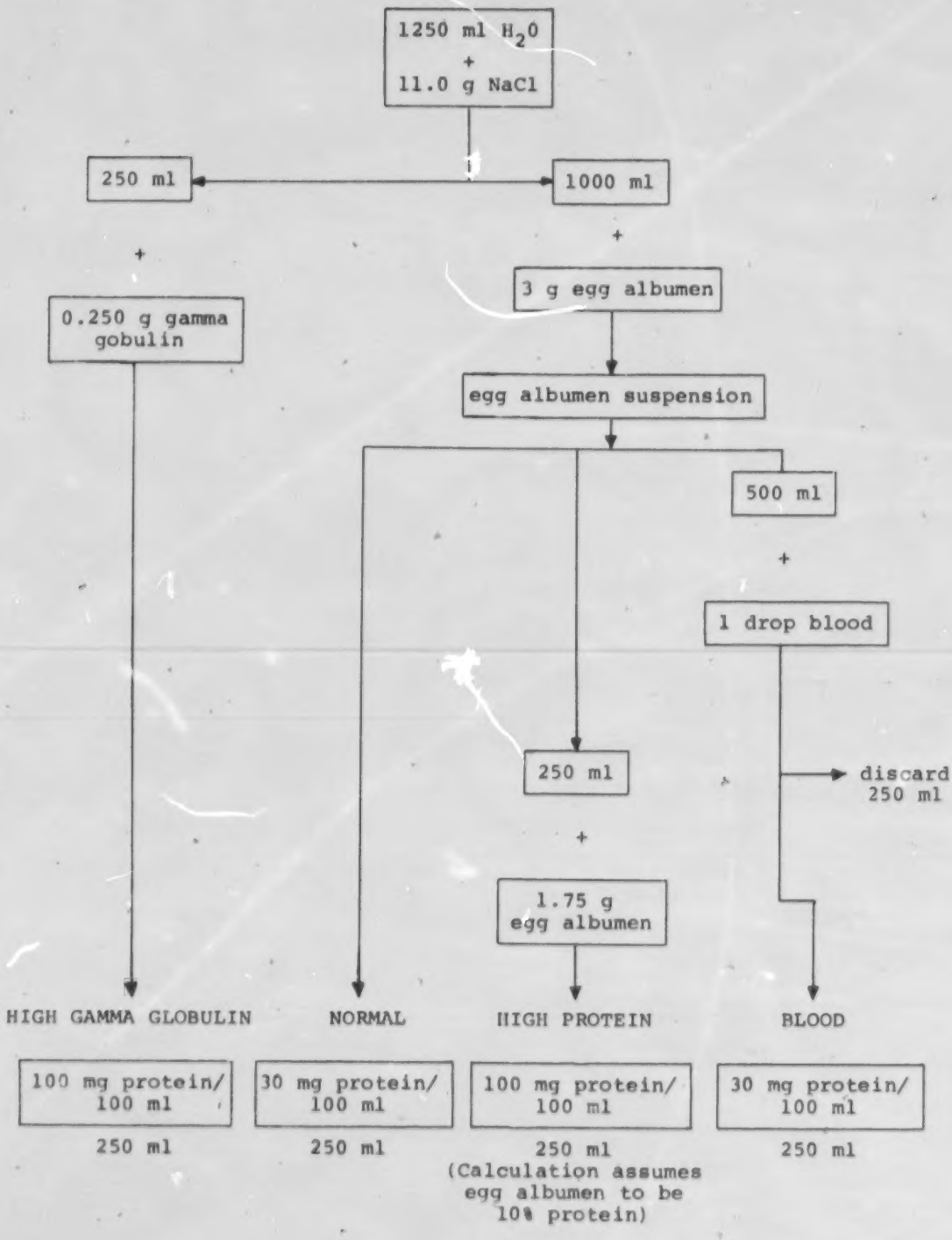
Simulated CSF with High Gamma Globulin: Dissolve 250 ± 20 mg bovine gamma globulin (sigma BG-II) in 250 ± 5 ml saline solution. The solution may be stored in the refrigerator up to a week.

Protein Reagent: Dissolve 10 ± 0.5 g sulfosalicylic acid in 200 ± 10 ml water. This reagent keeps well at room temperature.

Globulin Reagent: Add 140 ± 5 g ammonium sulfate to 200 ± 10 ml water. Shake until dissolved. If crystals remain, decant the clear supernatant solution. This reagent keeps indefinitely and should not be refrigerated.

FLOW CHART FOR PREPARING SAMPLES

(The final protein concentrations for each sample are shown in the boxes.)



ANTICIPATED RESULTS:

Our results of the test for high protein levels are provided.

normal:	%T=70-85	gamma globulin:	%T=60-70
blood:	%T=70-85	high protein:	%T=45-60

Note that the data indicate that at equal concentrations of protein, egg albumen gives significantly greater turbidity than gamma globulin. This is because albumin (the chief constituent of egg albumen) is more insoluble than the gamma globulin in the protein reagent. The difference in solubilities is due to differences in the molecular structures of the two proteins.

ANSWERS TO DISCUSSION QUESTIONS:

1. The brain diseases emphasized thus far in the Student Text are: multiple sclerosis, cerebral hemorrhage and epilepsy. Spinal fluid abnormalities are not normally found in epilepsy cases. Blood in the CSF indicates that cerebral hemorrhage is likely. High protein levels may be associated with either a cerebral hemorrhage or multiple sclerosis. High gamma globulin levels are usually associated with multiple sclerosis. (Note: you may wish to return to this question following Lesson 8 after discussing brain tumors and cerebral thrombosis. Both of these diseases may be associated with blood in the spinal fluid. Also, a brain tumor may cause high protein levels in the spinal fluid.)

2. The absence of red blood cells does not necessarily rule out the possibility of cerebral hemorrhage. Hemorrhaging may be confined to an area of the brain that does not leak blood into the spinal fluid.

LESSON 7: (A) CEREBRAL THROMBOSIS

(B) PSYCHOMETRIC TESTING

RATIONALE:

This considers cerebral thrombosis, an important and relatively common brain disorder in middle-aged and older people. Cerebral thrombosis is the fourth of the five diseases that will be part of the computer-diagnosis sequence (Lessons 9-13). Psychometric tests are often used to aid in diagnosis of brain diseases and to establish the location of brain damage when appropriate. A demonstration of a psychometric test is included in this lesson. It is designed not only to exemplify one kind of psychometric test but also to provide insight into how a psychometric test may appear to a patient who has suffered brain damage.

OBJECTIVE:

The student will:

- describe the nature and symptoms of cerebral thrombosis.
- list at least three examples of psychometric tests and explain how such tests aid in diagnosis of brain diseases.
- give an example of a coordination test and explain how such a test may aid in diagnosis of brain disease.
- state the relationship between atherosclerosis and cerebral thrombosis.

SEQUENCE: ST-7, Activity 7 (see below)

SUGGESTIONS:

1. Activity 7 is a psychometric test. It is presented in this manual rather than in the Laboratory Manual, because it is teacher centered and involves the

instructor as an "accomplice." While the activity might have been designed simply as a psychometric test, it was also developed to allow the students to experience the test as if they had brain damage. To achieve this goal, Part II of the test is designed so that students will be frustrated by their inability to answer questions quickly and by their inability to process two kinds of information simultaneously--an experience very common to stroke victims. Part II of the test deceives the students in that they will assume that they are being given a standard test of brain dysfunction.

In Activity 7 it is essential that students be allowed to suffer some frustration. It is important that they be unaware during the activity of the deception. Later, the activity should be discussed, along with the rationale for the deception. If this activity has been used in your school recently, it is possible that some students will recognize the activity and give the deception away. If this happens, you might select subjects from outside the class and allow your students to participate in a repetition of the test.

2. Psychometric tests are presented very briefly in this lesson. We suggest that you invite the counselor into the classroom to discuss and show samples of some of the tests used in your school. It might also be interesting to invite a Special Education instructor into the classroom to talk about his or her use of psychometric tests.

3. Strokes are very common among the elderly, and some students may have relatives who have recently suffered one. Such students might be interested in reading V. E. Griffith, A Stroke in the Family, Delacorte Press, N.Y, 1970. This book suggests some ways for friends and relatives to help rehabilitate a stroke victim.

4. You could have your class review the earlier discussion of coronary thrombosis (Unit III, Section 9-2) and compare this condition with cerebral thrombosis.

5. Coordination tests could be demonstrated in the classroom. A few such tests are mentioned in ST-7. Two additional ones are given below.

Walking test--Have the subject walk across the room with eyes open and back with eyes closed. Then have the subject walk touching heel to toe of alternating feet. (The neurologist would watch to see whether the movements are smooth and without tremor, the posture is erect and the arms swing normally. Failure to perform these tasks well could indicate damage to the cerebellum or to the nerves connected to the cerebellum.)

Hand-coordination test--Have the subject pat his knees, alternating pats with palm down and palm up. (The neurologist would observe how quickly these movements are made. This test also checks for damage to the cerebellum or its connecting nerves.)

ACTIVITY 7: PSYCHOMETRIC TESTING

This activity is to be carried out in two parts. The scoring procedure is given in Part III.

GROUND RULES: (for first two parts)

1. Designs will be presented in a particular order.

2. The students may not touch their pencils while a design is on the screen. When they have finished drawing a design, or writing a sum, they are to put their pencils down. This will be the signal to you that everyone is ready for the next design or number combination.

3. The students may not write down the numbers you call out, only their sum.

4. Students may cross out a faulty drawing and redraw it, or cross out an incorrect sum and rewrite it.

PART I: Memory for Design

MATERIALS:

2 sheets of paper, 8 1/2 x 11"

pencils or pens

ruler

9 designs (the designs are given after this activity)

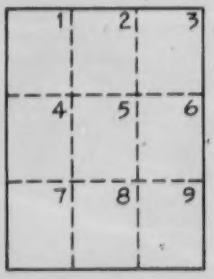
projector (see Teaching Notes)

PROCEDURE:

1. Explain that you or an assistant will be projecting a series of nine designs on the screen as part of a psychometric test. Each design will be on the screen for about five seconds. After a design is off the screen, the students are to reproduce it on paper as accurately and completely as possible. They will have as much time as they need to make their drawings.

Further explain that when they have finished each drawing, you will read aloud a series of three numbers. They are to add the three numbers mentally and write the sum below the last design drawn.

2. Have the students prepare a data sheet --to take a sheet of paper, approximately 8 1/2 by 11", rule lines dividing it into nine rectangles of about equal size and number the nine rectangles. The students should have two or three pencils handy (or a pen). Otherwise, broken pencil points may interfere with the steady presentation of designs and numbers.



3. Review the ground rules.

4. Present the first design for five seconds. Be sure that the design is presented with the proper orientation. You may wish to use an overhead projector for this step. See Teaching Notes.

5. When the five seconds are up, remove the design from view and allow the students as much time as needed to reproduce the design in the appropriately numbered rectangle.

6. Read aloud the three numbers that the students will total. For design 1, the numbers are: 1-2-4. Have the students add the three numbers mentally and record the total in the rectangle with the first drawing.

7. Repeat the cycle for Designs 2 through 9 (i.e., present a design for 5 seconds, remove it, allow the students to reproduce the design from memory, provide the three numbers the students are to add). The numbers to add for each design are given below.

PART I--Design Number

1. 1-2-4	4. 8-4-11	7. 14-9-16
2. 4-2-5	5. 11-3-11	8. 14-9-16
3. 6-1-12	6. 9-22-4	9. 7-17-18

8. When all nine designs of this part have been presented, proceed to Part II. Scoring will not be done until Part III.

PART II: Memory for Design with Interference

MATERIALS: Same as Part I

PROCEDURE:

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1. When Part I has been completed, have the students put aside their papers. Explain that Part II is intended to be difficult and that there will be a discussion following the task on how well the students did and how they felt themselves reacting. Also explain that Part II differs from Part I in only one respect. The ground

rules are the same. But this time, the design and the three numbers to be added will be presented simultaneously. As soon as the design goes off the screen, the students are to pick up their pencils and first draw the design from memory. Then, and only then, they are to write down the sum of the numbers.

2. Repeat Step 2 of Procedure Part I.

3. Present Design 10 for five seconds. As soon as this design is projected, read off the three numbers (1-2-3) they are to add.

4. Repeat Step 5 of Procedure Part I. (Remember that the students are <u>not</u> to write down the sum before they complete the drawing.)

5. Repeat the cycle for Designs 11 through 18. The numbers to add for each design are shown below.

PART II--Design Number

10. 1-2-3	13. 4-6-6	16. 14-4-16
11. 3-2-1	14. 7-2-9	17. 9-11-14
12. 3-4-3	15. 11-1-12	18. 16-19-13

<u>PART III</u>: Scoring and Evaluation

<u>PROCEDURE</u>:

1. Students should exchange papers for scoring purposes. The scoring is somewhat subjective and approximate. Project the slides in order during scoring, so that the students have access to the correct designs. Scoring is as follows.

Score 2--Design is drawn exactly or almost exactly as originally projected with no major features missing and with the design oriented as projected.

Score 1--The design drawn is somewhat distorted but is still recognizable as being an approximation of the original projection. Minor elements may be missing. The orientation of the predominant form is as projected.

Score 0--The design drawn shows gross distortions, marked incompleteness and/or inversions of the dominant figure from the correct orientation.

Note that the sums are not scored at all.

2. Have the students total their scores on Part I and Part II separately. You may wish to tabulate the results on the chalkboard.

3. Discuss the results and observations. Determine whether the Part I scores are significantly higher than those of Part II. Have the students discuss how they felt while performing Part II. Explain the rationale behind the activity (see Teaching Suggestion 1).

4. The following points should either come out during the discussion or be brought to the class' attention.

a. There are five separate operations involved in responding to the tasks. These include:

(1) "seeing" the design (retina to optic nerve to cortex)

(2) giving meaning to what is seen

(3) remembering what was seen

(4) instructing the muscles

(5) using muscles to reproduce the design

Any of these operations may be impaired in a patient with a brain disorder.

b: It is anticipated that the students will generally do quite well on Part I. However, Part II is structured so that most students will do poorly, especially with the more complicated drawings, partly because of the problem of interference. (Interference involves trying to use the brain in more than one way at a time.)

The second task is clearly more difficult because of the need to hold and/or process two kinds of information simultaneously. Summing the numbers interferes with the design portion of the task. In some brain disorders the patient finds it difficult to concentrate because other thoughts keep interfering. The two-tasks-at-once situation is meant to imitate this condition. From it, the students may get some idea of how the brain-disease patient feels in trying to concentrate on even one task. Be sure to explain that the Part II of the test is designed so that normal persons will fail. An individual with serious brain damage would suffer the same combination of failure and frustration with Part I of Activity 7 as a normal student typically experiences in Part II of the activity.

c. The designs of the brain-disease patient tend to be disorganized on the paper. The patient may have trouble remembering and needs to get the design on paper quickly before it fades from memory. The students may find themselves calculating a sum and saying the sum to themselves while making the drawing in order to keep the sum in their memory. Brain-disease patients are often observed saying aloud such things as, "Looks like a bar with anchors on each end," to help retain the memory.

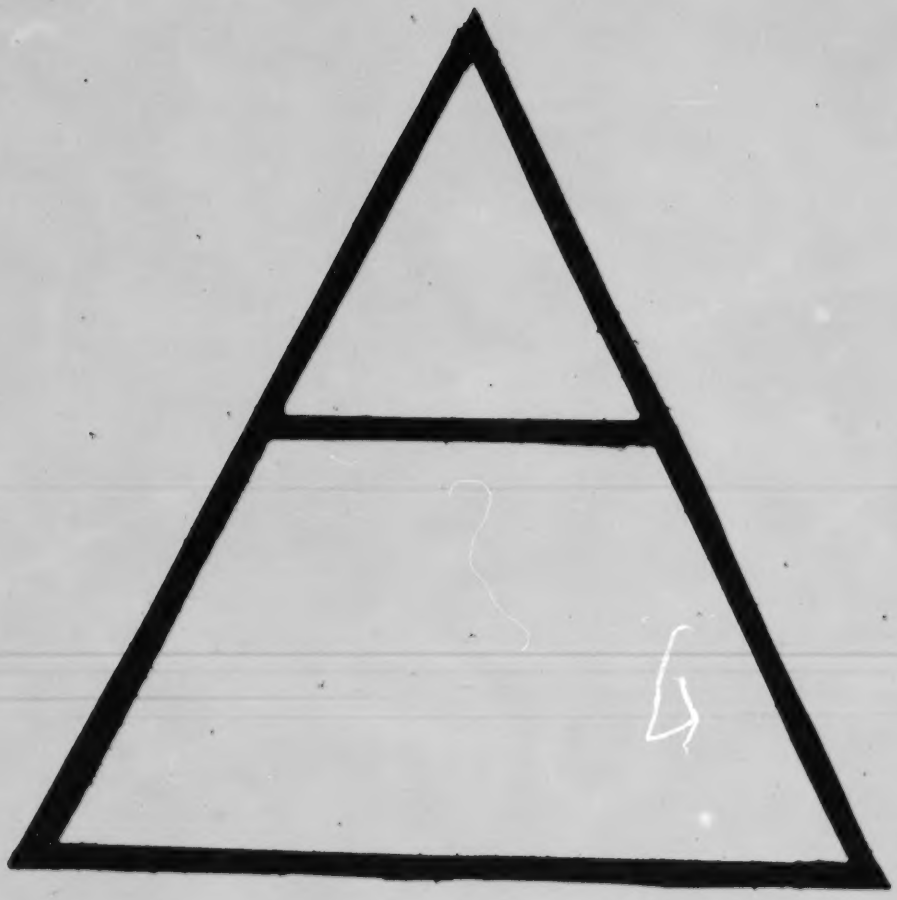
d. Perseveration (in this case, drawing a design similar to one seen earlier) is considered symptomatic of a brain disorder if it occurs in Part I.

e. Brain disorders lead to frustration. The patient will often do just so much on a task and then give up. In Part II, students may partially give up by focusing on either the designs or the numbers, but not both. There is a large range of "normal" responses to the tasks; some people do better than others because of stronger copying or mathematical abilities. When the tasks become too difficult to do both, people will generally choose their stronger abilities, e.g., concentrating on making drawings if that is their strength.

f. In Part II, some students may come up with elaborate systems for remembering well. This corresponds to what a bright person with brain damage might do on Part I: compensate for the deficiency. In psychometric testing it is important to correct for age and other factors. An old person can show some deterioration in ability or such tests without a diagnosis of severe brain dysfunction.

g. The results of a psychometric test may look poor because the patient was having a "bad" day. These tests need to be interpreted in the context of a pattern of findings, and repeated testing is often used.

h. The students may notice that they are bothered in Part II by things that were easily ignored during Part I (e.g., noises outside the room). The brain-damaged patient does best when things are very calm and quiet.



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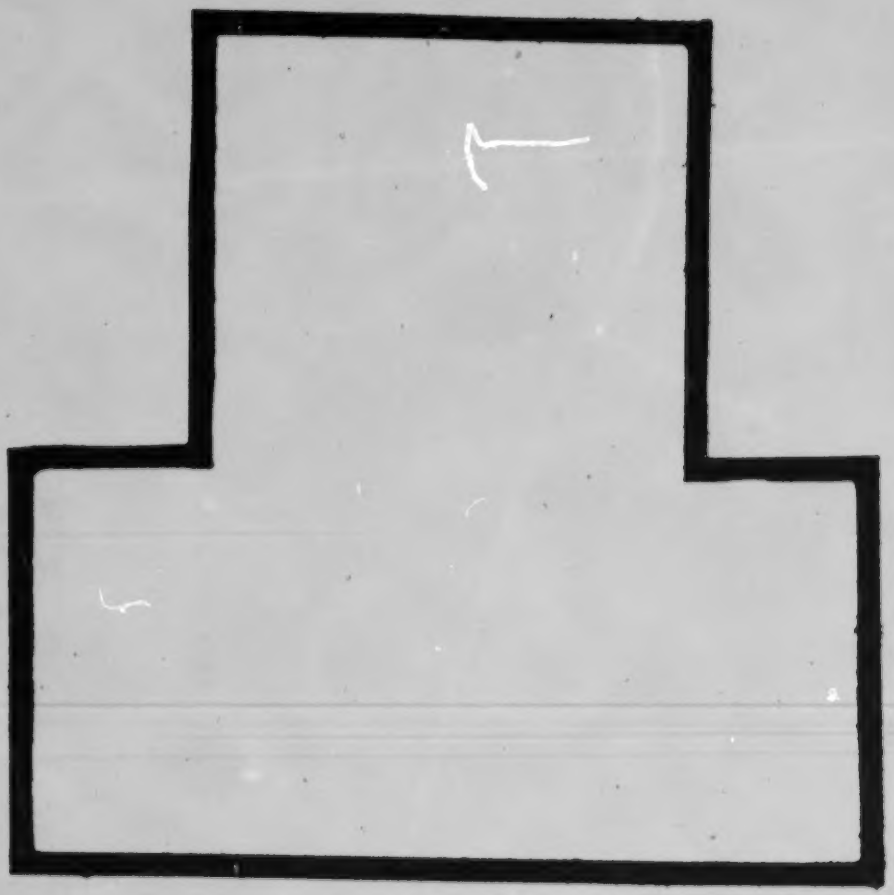

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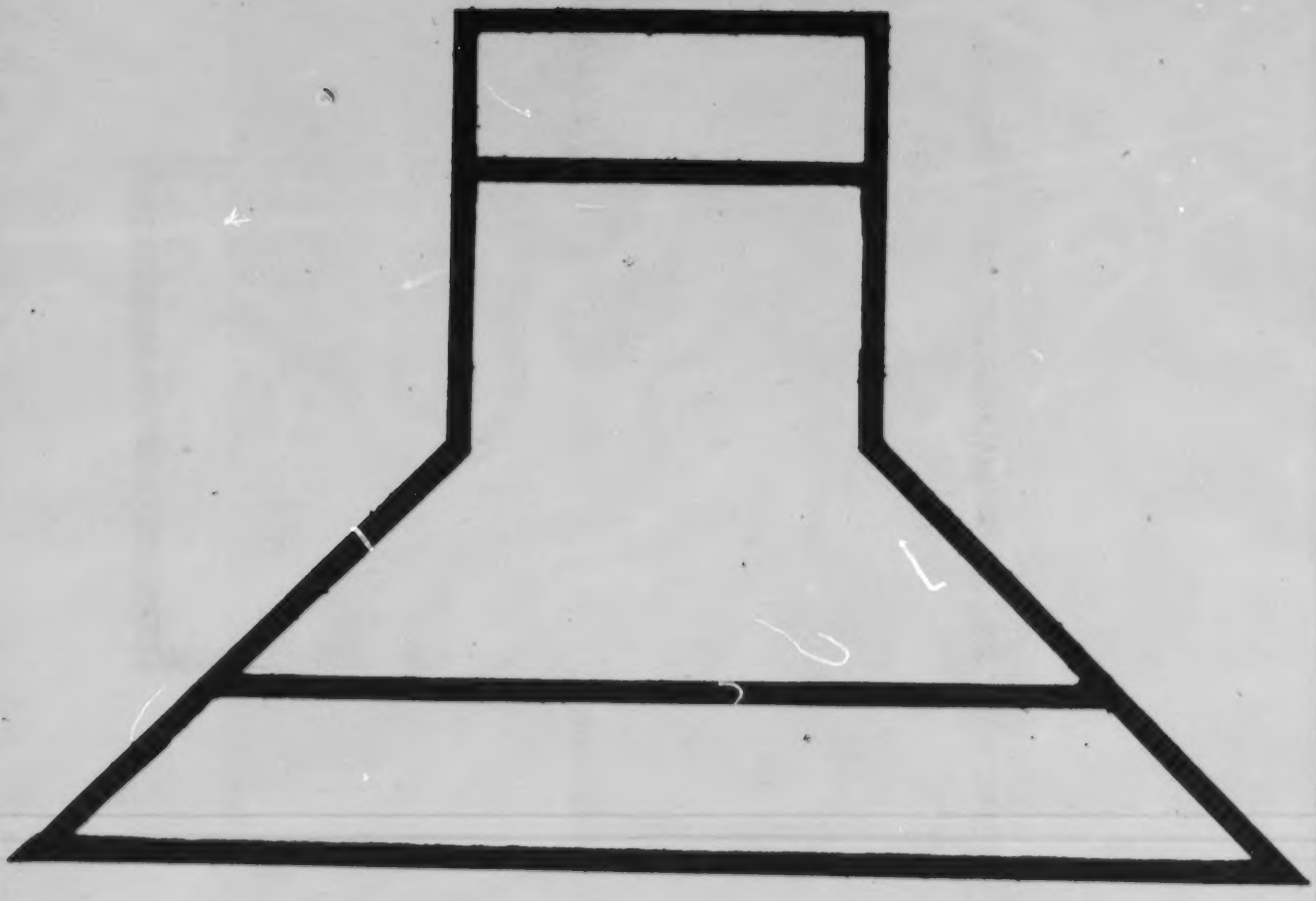

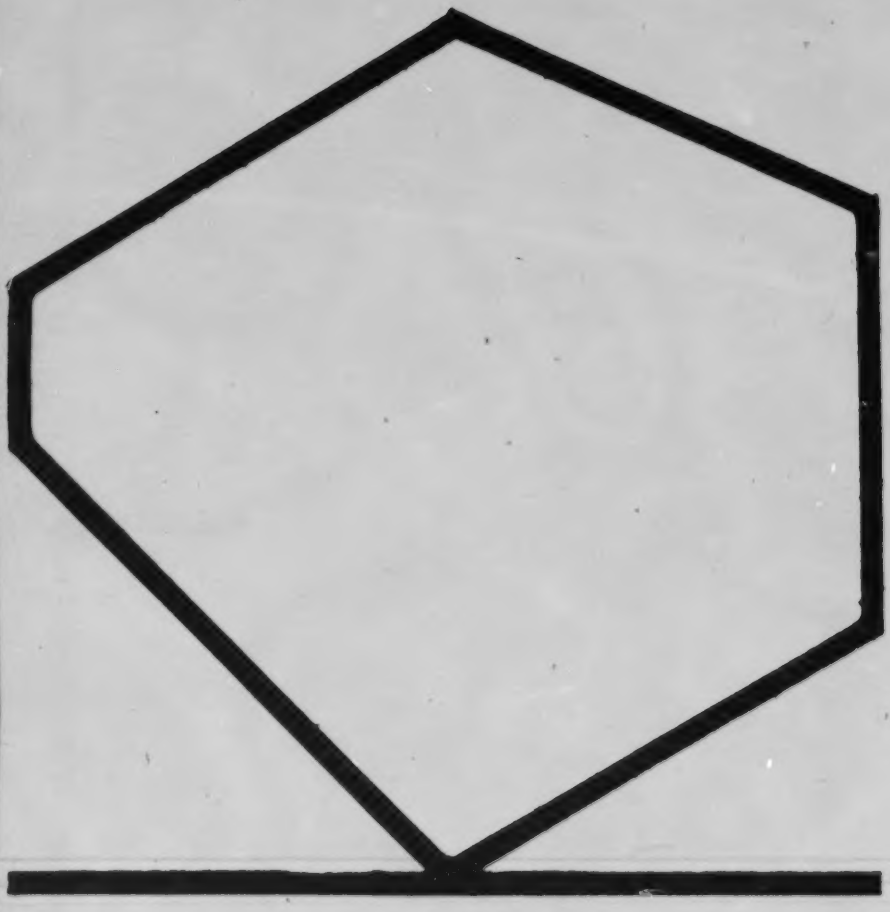

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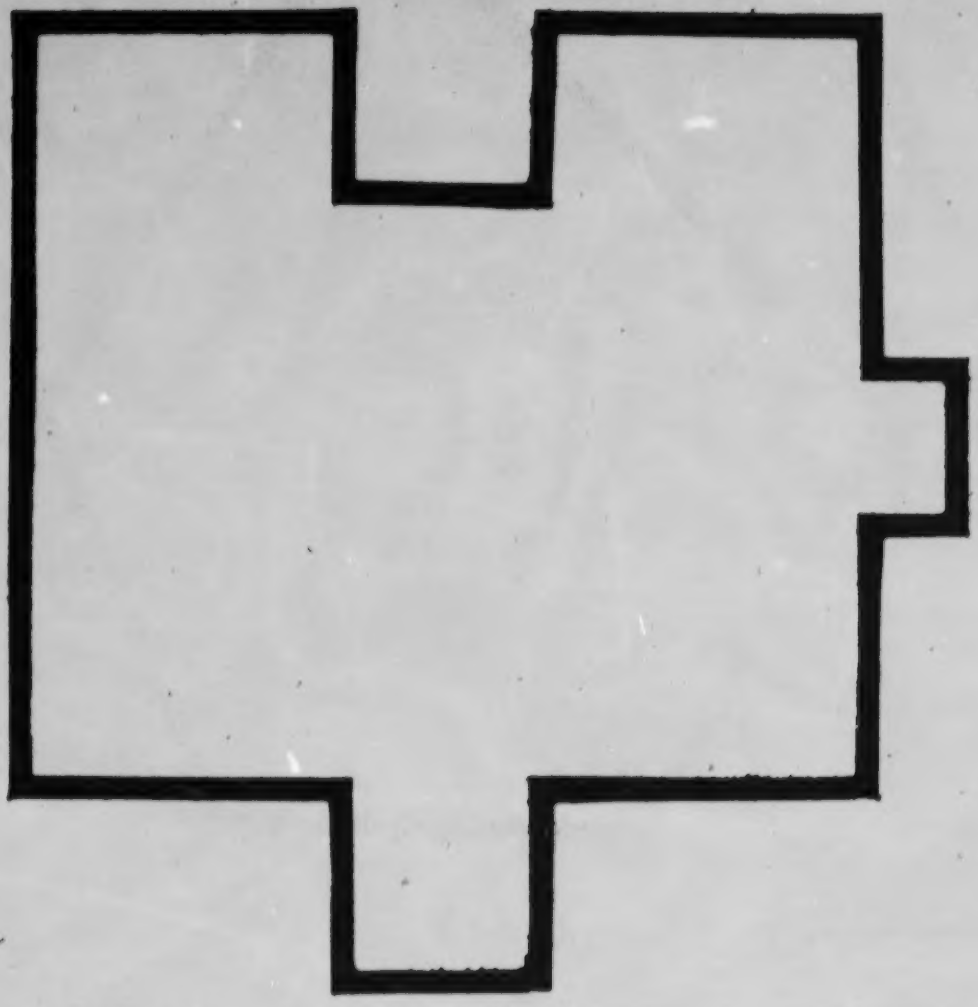

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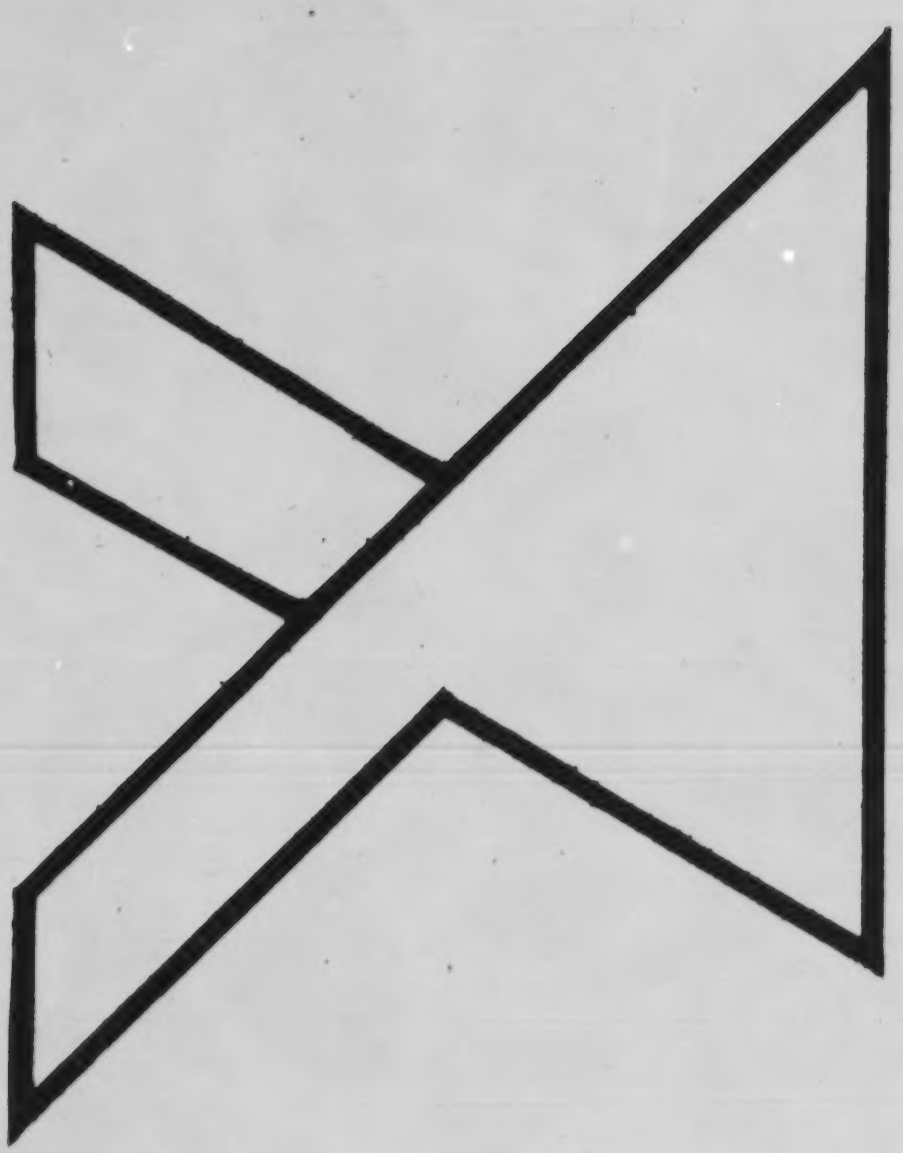

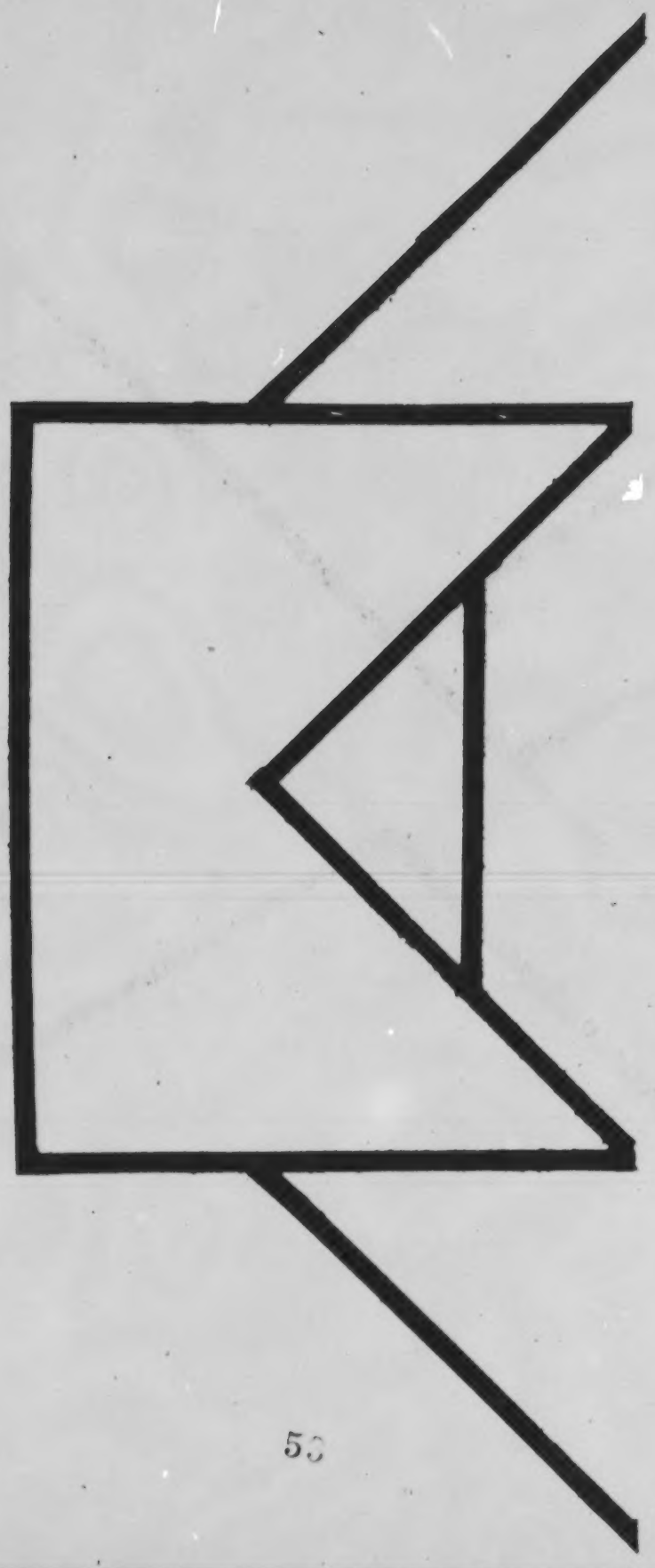

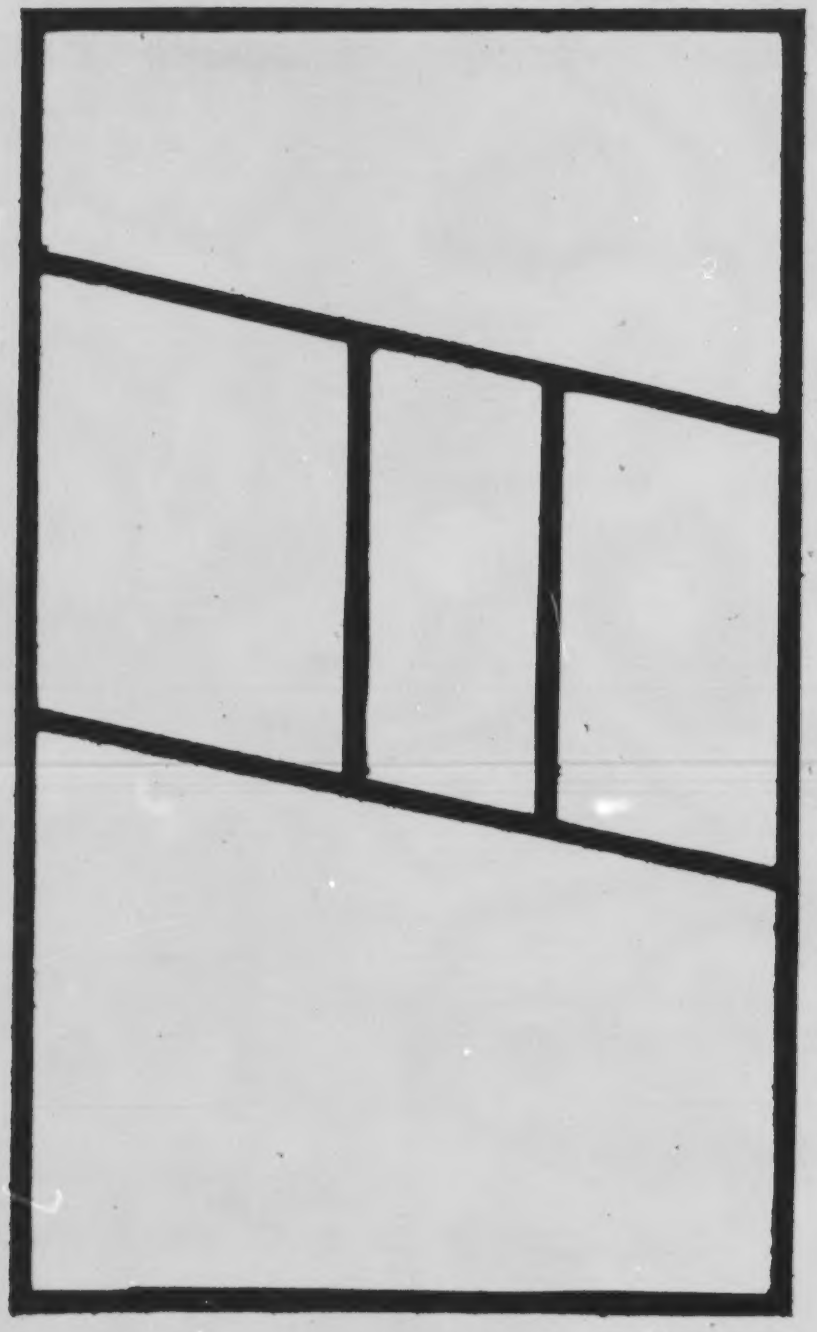

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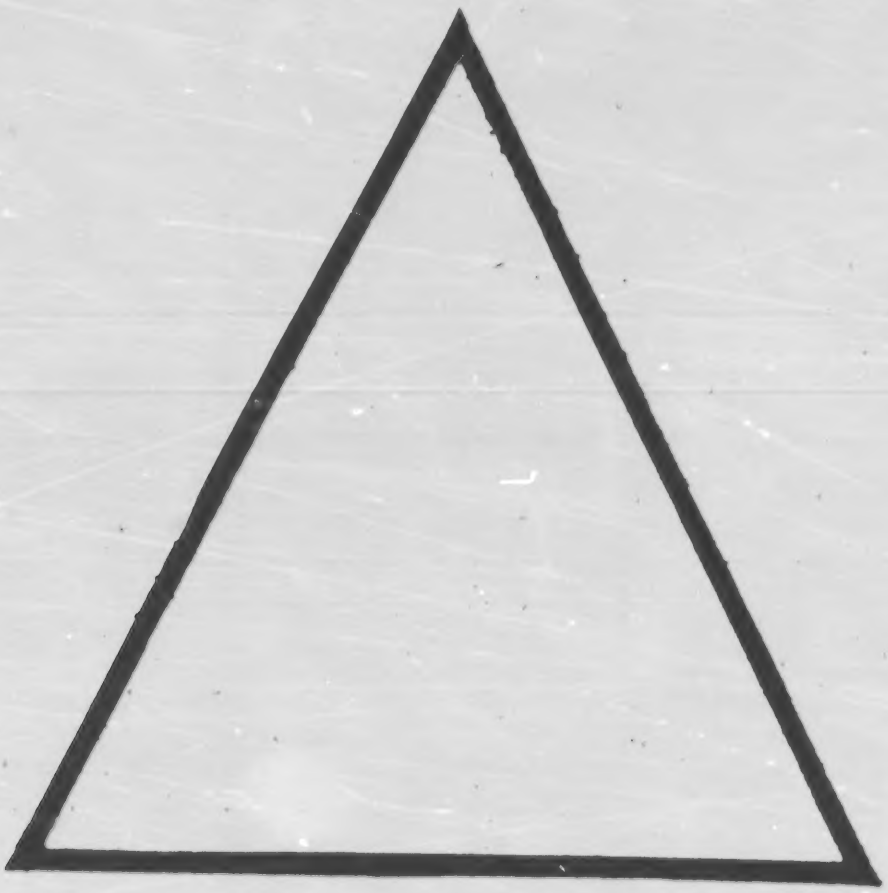

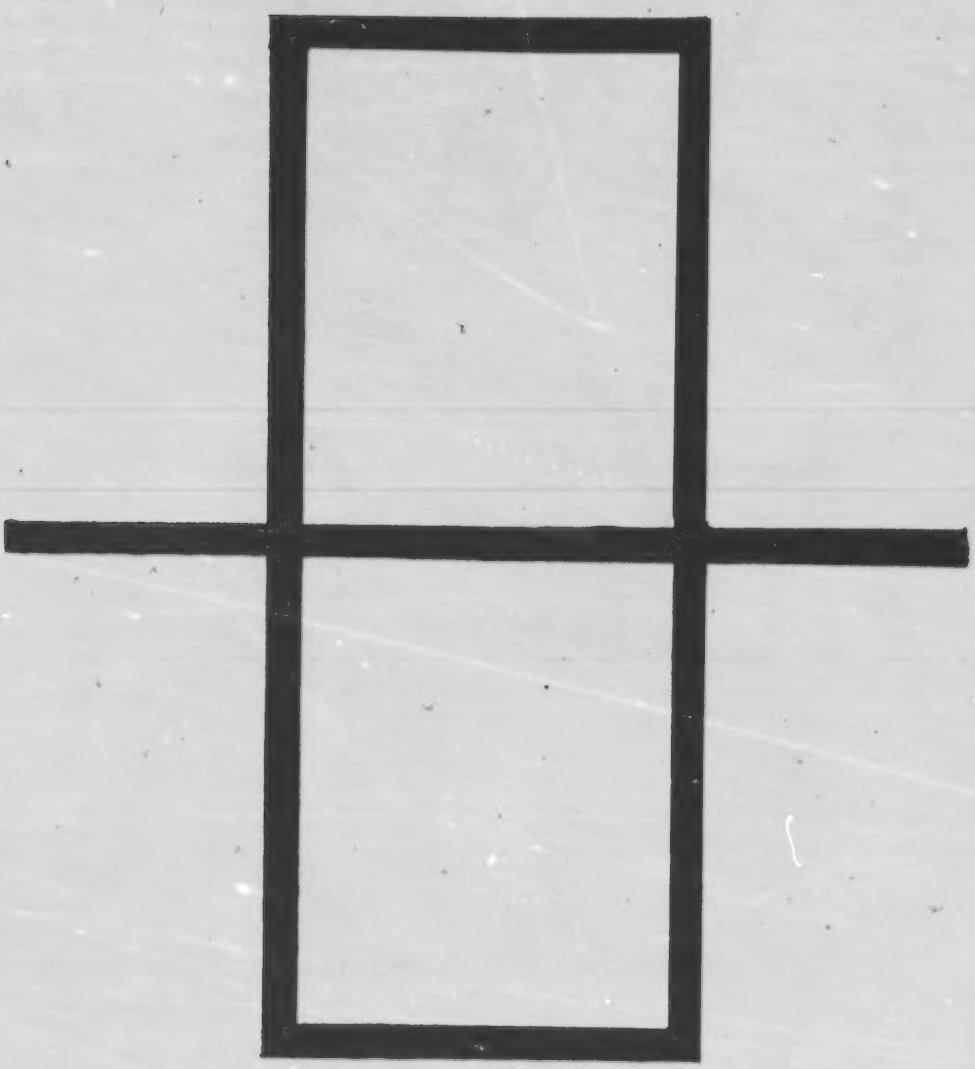

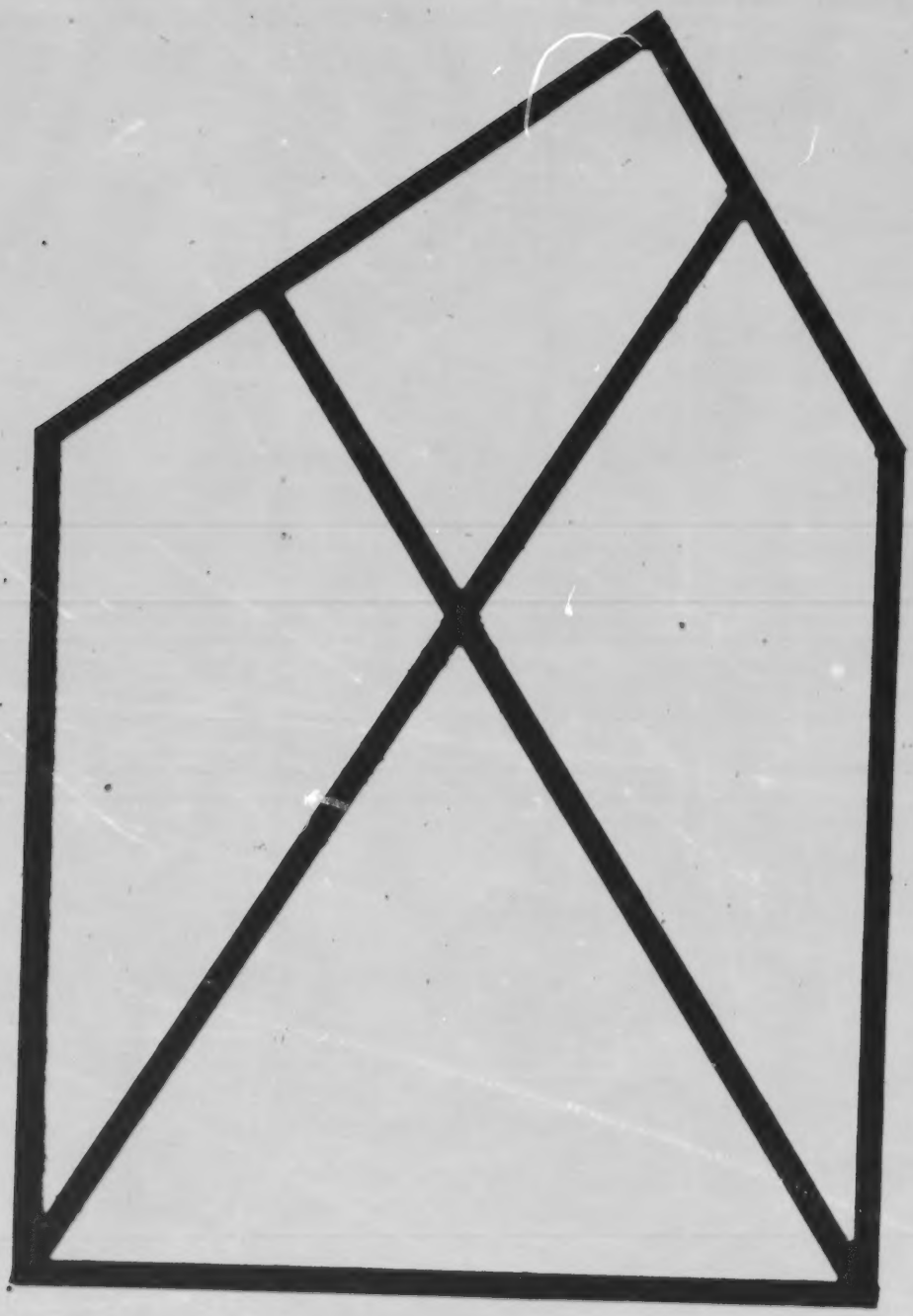

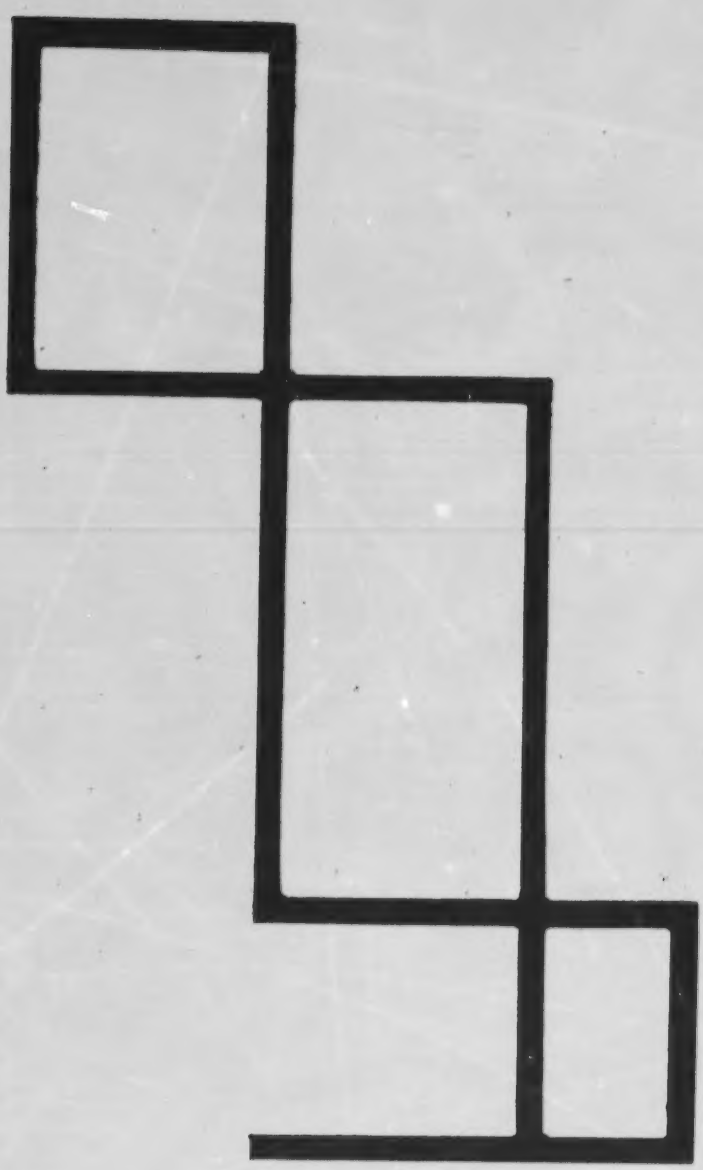

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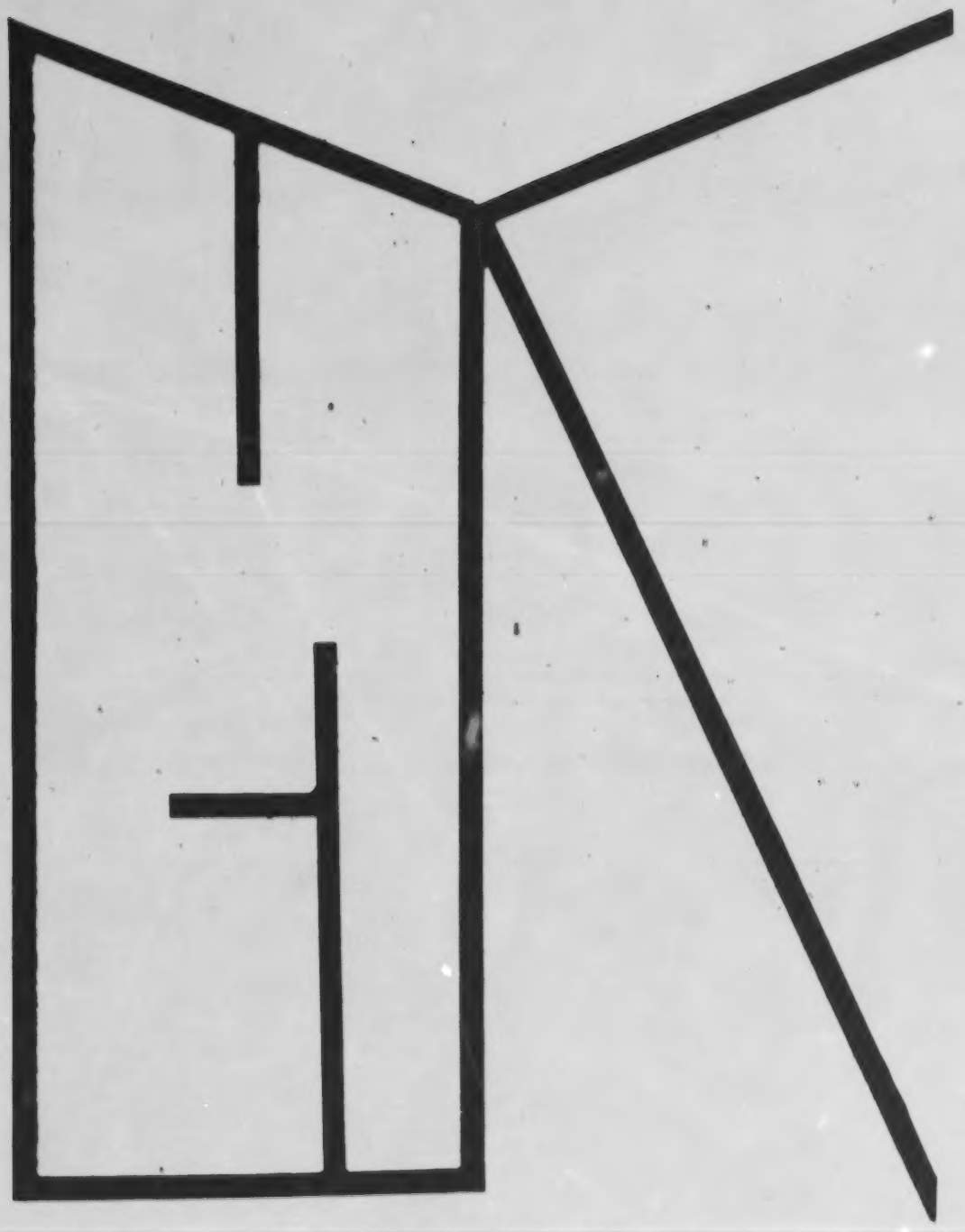

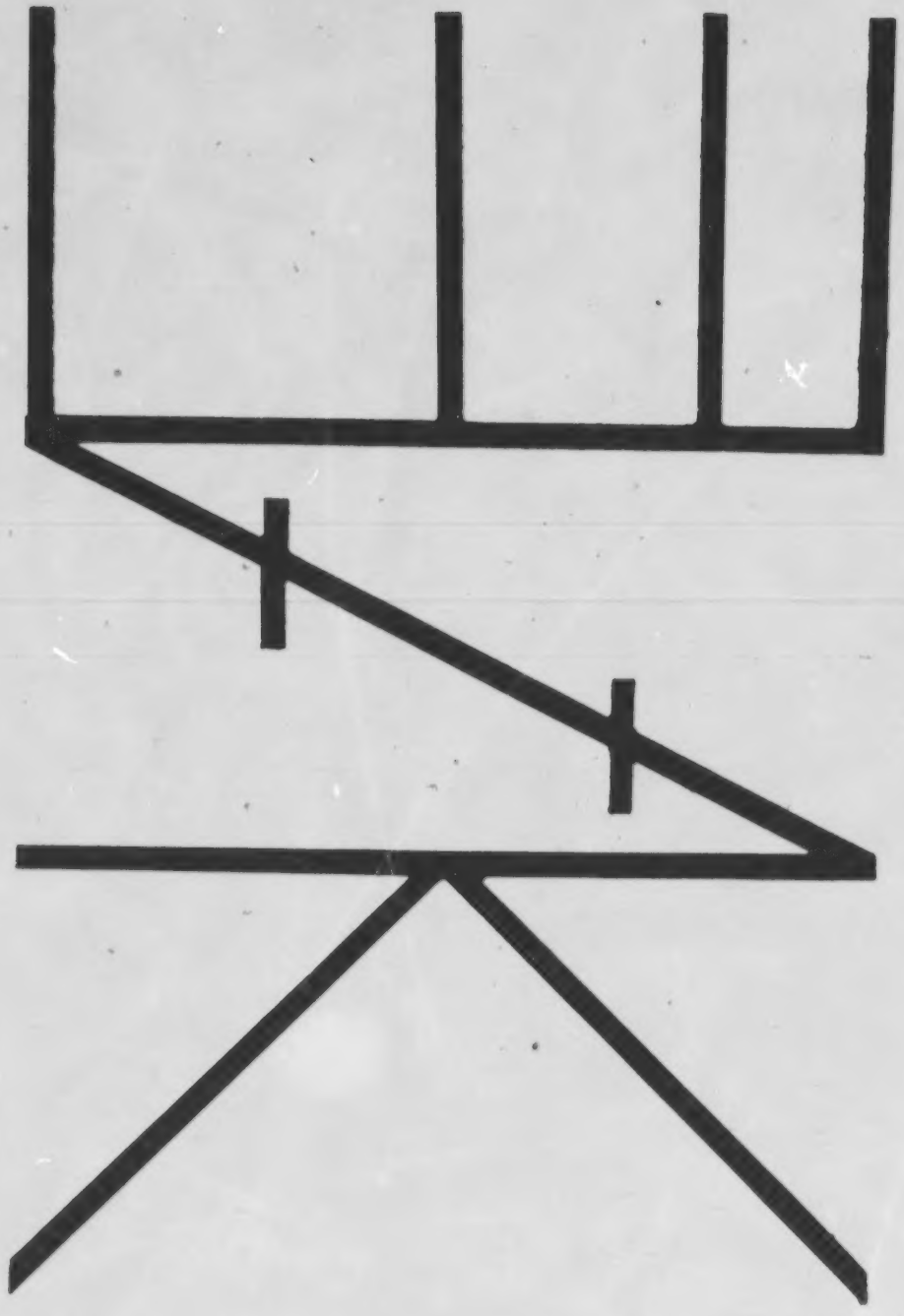

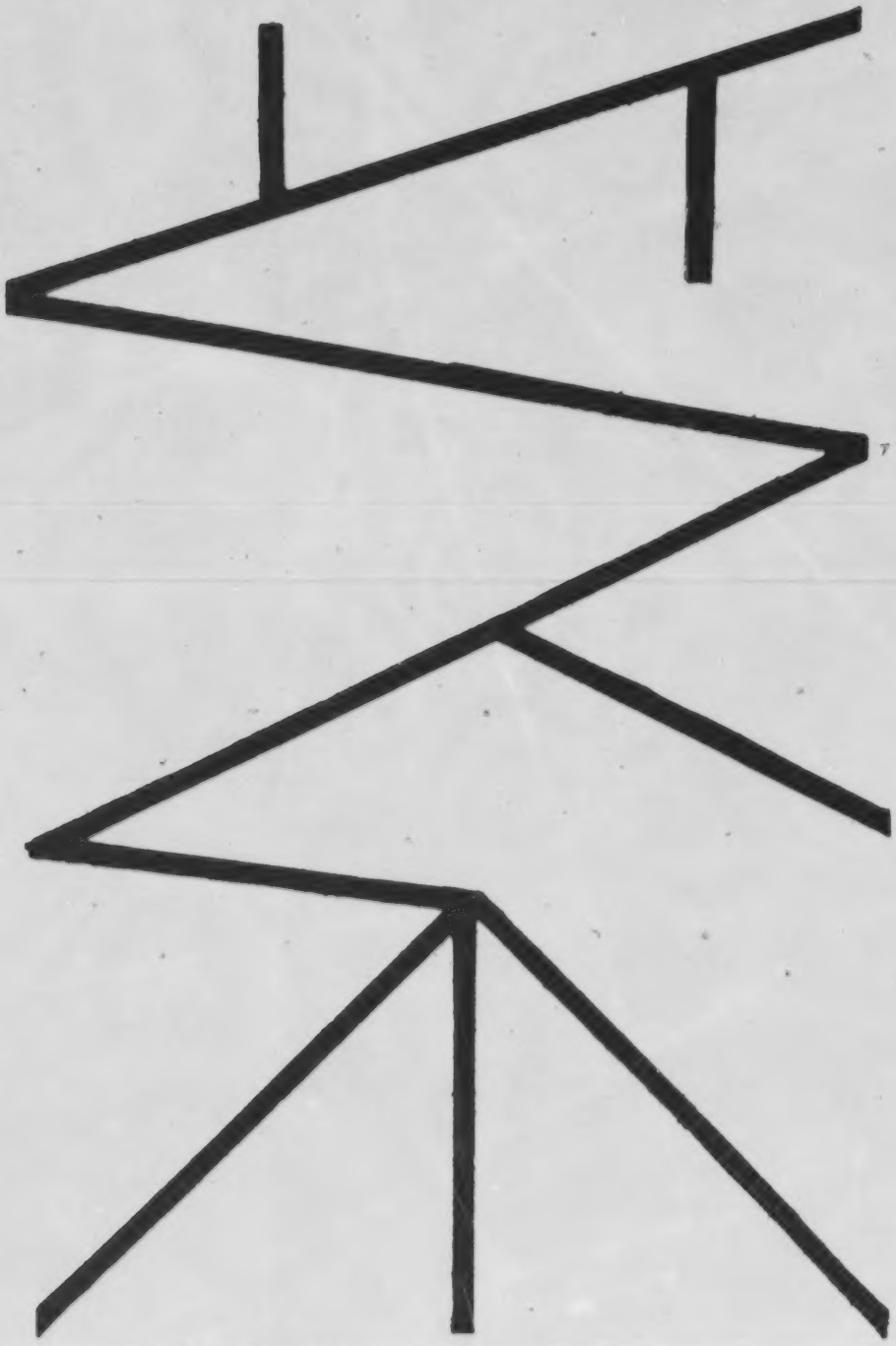

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INFORMATION ON ACTIVITY 7:

TEACHING NOTES:

1. The purpose of this activity is (1) to demonstrate a psychometric test for brain damage and (2) to allow the students to experience the test as if they had brain damage. (See Teaching Suggestion 1.)

2. Anticipated time: one period and part of a second period for discussion of the results.

3. After the students complete Part III of the activity, you should reassure them that it is normal to do poorly in Part II of the test--that a low score on Part II does not indicate brain damage. However, it may be best to schedule the discussion of the activity for another day so the students have time to "cool off." This might permit a more objective analysis of the results.

4. There are several ways in which the design may be prepared for presentation. The simplest is probably to make transparencies of each of the 18 designs provided in this manual. Another possibility is to photograph the designs and make slides for projection.

5. In Part II, it is difficult to present a design, provide the three numbers and keep track of the five-second intervals simultaneously. In addition, the three numbers to add should be presented with a particular timing to achieve the objectives of the activity. One way to present the designs and keep track of the time intervals is as follows:

Give first number and turn on design simultaneously.

(Count mentally--one one-thousand, two one-thousand)

Give second number.

(Count mentally--one one-thousand, two one-thousand)

Give third number and turn off design simultaneously.

Move the next design into position while the students are working.

MATERIALS: (for class of 30)

60 sheets of paper, 8 1/2 x 11"
30 to 60 pencils or pens
30 rulers
18 designs
1 projector and screen

ANTICIPATED RESULTS:

Students will score much higher in Part I than in Part II. They will find Part II frustrating and will respond in a variety of ways.

LESSON 8: A. BRAIN TUMORS

B. VISUAL-FIELD EXAMINATION

C. REVIEW

RATIONALE:

ST-8 describes brain tumors, the fifth and last of the brain diseases that will be part of the computer-diagnosis activity. Since diagnosis of brain diseases often relies on visual-field defects, Lesson 8 considers visual field testing. Visual-field defects may give a clue to a pituitary tumor before any other symptoms

are noticed. In LA-8, the students locate and measure the area of their blind spot for each eye by a technique similar to the one used to measure visual fields.

Lesson 8 completes the sequence of lessons on the nervous system and brain disorders. A review set for these eight lessons is provided.

OBJECTIVES:

The student will:

- list the clinical findings used to diagnose a brain tumor.
- state how visual-field testing may be utililized in diagnosis of brain tumor.
- state the significance of high intracranial pressure.
- state the relation of the pupil, the retina and the optic nerve to visual perception.
- explain how X-rays and ultrasound may aid in diagnosis of a brain tumor.
- map the location of the blind spot in each visual field of a subject.

SEQUENCE: ST-8; LA-8; Review

SUGGESTIONS:

1. This is the last lesson in the sequence of lessons on brain diseases. It might be of interest to review the sequence by modifying the case history in minor ways and asking the students how the diagnosis would be affected. For example, suppose the BP reading were 150/95 instead of 130/80. This change might suggest cerebral thrombosis as a diagnostic possibility.

2. The discussion of visual perception is deliberately terse since the subject will be considered in some depth later in the unit. It was introduced here to explain the relationship between visual-field testing and brain tumor.

INFORMATION ON LABORATORY ACTIVITY 8

TEACHING NOTES:

1. The purpose of this activity is to acquaint the students with a procedure used in visual-field testing. It also demonstrates that sizable gaps in the visual fields can easily go unnoticed.

2. Anticipated time: one period.

3. Since the blind-spot map of a typical subject will spread horizontally 65-70 cm, about .75 m of chalkboard per subject is required, or around 12 m of chalkboard for 15 pairs of students. If chalkboard space is inadequate, a piece of dark construction paper about 1 meter by 30 cm taped to a wall is more than adequate for mapping the blind spots of a subject.

4. Some variation in the size and location of blind spots is normal. Students should not be surprised if their blind spots differ in size and location from their classmates'.

5. You may wish to review this activity after the students have studied optics and vision later in this unit.

MATERIALS: (for 15 set-ups)

15 scissors

15 paper clips

15 meter sticks (as few as 4 or 5 will suffice)

15 pieces of chalk

several sheets of white paper

several transparent tape dispensers

30 sheets graph paper

ANTICIPATED RESULTS:

The blind spots, as measured on a screen one meter away, show up as circular areas about 10-15 cm in diameter at or near the horizontal axis of the visual field. They are displaced from the center of vision 25 to 30 cm toward the left and the right for the left and right eye, respectively, when the subject's eyes are one meter from the chalkboard.

ANSWERS TO DISCUSSION QUESTIONS:

1. The blind spot of each eye is within the visual field of the other eye.

2. The procedure is not suitable for mapping the outer edges of our visual fields. Normally, the angle of the combined visual fields of both eyes is 180° or even more. Thus a flat surface cannot be used to obtain the necessary measurements. In professional testing, the subject is tested with a hemispherical screen; the screen is at a constant distance from the eye.

3. Answers will vary. Also see Anticipated Results.

KEY--REVIEW SET 8:

1. medulla.

2. cerebrum or motor cortex.

3. true.

4. true.

5. neurotransmitter.

6. alpha waves--a relaxed state of mind.

   beta waves--ordinary thinking, sleep during dreaming.

   delta waves--sleep when not dreaming.

7. more easily.

8. An instrument that measures blood pressure would be connected to the patient and to a display device that signals when the blood pressure is below a certain level. The patient would attempt to get the signal to go on and to keep it on as long as possible. Eventually the patient would be able to lower the blood pressure without a measuring device or an external signal.

9. a. parasympathetic; b. parasympathetic; c. sympathetic; d. sympathetic.

10. A. axon of sensory neuron; B. synapse; C. axon of motor neuron.

11. Cerebral hemorrhage involves significant bleeding in the brain. This condition is most often triggered by hypertension, although the hemorrhage can result from a head injury. Cerebral thrombosis is caused by a clot in one of the blood vessels in the brain. The effect is to deprive a part of the brain of oxygen and nutrients. The result of such deprivation is likely to be death of some part of the brain. Cerebral thrombosis is associated with atherosclerosis.

12. Tests for total protein concentration, gamma-globulin concentration and presence of red blood cells.

    High protein concentration: cerebral hemorrhage, multiple sclerosis and possibly brain tumor.

High gamma globulin concentration: multiple sclerosis.

Red blood cells in CSF: cerebral hemorrhage and possibly brain tumor.

13. Category test (patient sorts out objects by size, color, etc.); tactile performance test; rhythm test; trial-making test; aphasia test; I.Q. test; personality test.

Psychometric tests are used to estimate the location and degree of brain damage (especially in cases in which there are no motor or sensory deficits).

14. With an ophthalmoscope, a physician can detect evidence of hypertension (arteries much narrower than veins) and high intracranial pressure (blurred optic disks).

Other devices: ultrasound machine (ultrasonic generator, echoencephalograph), X-ray machine, EEG, computer, colorimeter, etc.

15. a. cerebral hemorrhage; b. brain tumor.

LESSON 9: DIAGNOSING BRAIN DISEASE

RATIONALE:

The purpose of this lesson is fourfold: (1) to review several brain diseases the students have studied thus far in the unit, (2) to introduce the concept of a computer as a diagnostic aid in medicine, (3) to begin a multi-day activity in which students design and construct a simple computer for diagnosing brain disease and (4) to reinforce the treatment of symbolic logic given in Biomedical Mathematics.

OBJECTIVES:

The student will:

- review the relationship of the following clinical findings to multiple sclerosis, cerebral thrombosis, cerebral hemorrhage, epilepsy and brain tumor:

  convulsions
  continuing brain dysfunction
  blood in CSF
  high total-protein concentration in CSF
  high globulin concentration in CSF
  high CSF pressure
  rate of onset
  abnormal skull X-ray

- state whether a given clinical finding is a symptom, sign or finding.

- write a simplified truth table relating the above diseases to the above clinical findings.

- state which of the above diseases is a possible diagnosis, when given specific information on the presence or absence of the above clinical findings.

- state how computers may be used in the diagnosis of disease.

SEQUENCE: ST-9; Activity 9

SUGGESTIONS:

1. Lesson 9 begins an application of concepts of symbolic logic that the students have been studying in Biomedical Mathematics. Unless you are thoroughly familiar with symbolic logic, it is essential that you read carefully Sections 1 to 8 in Biomedical Mathematics, Unit IV. Working the problems (particularly Problem Sets 4 to 8) will also be of benefit, if you can find the time. Even if you are familiar with symbolic logic, the circuitry symbols may be new to you. In this case, you might start reading the Mathematics Student Text at page 21 (Section 5).

In this sequence of lessons, the timing of the Science and Mathematics courses must be kept in mind. The Science lessons are dependent upon Mathematics lessons, and therefore the Science lessons must follow the Mathematics lessons. In particular, Mathematics Lesson 8 must be completed before Science Lesson 10 is presented. In the Biomedical Mathematics Instructor's Manual, the mathematics instructor is encouraged to attend the Science class when Laboratory Activity 10 and Problem Set 11 are presented.

If the mathematics instructor has a free period during your class, Lessons 9 through 13 provide an excellent opportunity for team teaching. Conversely, it may be advantageous for you to attend some or all of the mathematics classes on symbolic logic.

2. ST-9 distinguishes between symptoms, findings and signs. In reviewing the distinction between the three terms, you could list a series of clinical findings and ask the students to identify whether each clinical finding is a symptom, sign or finding. A few clinical findings and the classification of each follow.

Dizziness (symptom), dark skin spots (sign), high blood cholesterol (finding), stomach pains (symptom), abnormal EEG (finding), hemolytic streptococci in throat swab sample (finding), wax in ears (sign), pain caused by wax in ears (symptom), constant thirst (symptom).

3. You may wish to read or refer students to the following article on the brain-scan X-ray technique. R. Gordon, G. T. Herman and S. A. Johnson, Scientific American, Vol. 233, No. 4, 56 (1975).

4. Sometimes an analogy is made between a computer and the human brain. You may want to comment on this analogy and on its limitations. Both a brain and a computer process information and deal with inputs and outputs, but the similarity is superficial. One key difference is in their relative complexity. The brain contains over ten billion neurons and each of these connects to as many as 10,000 other neurons. Another, more fundamental difference is that computers cannot initiate independent actions.

INFORMATION ON ACTIVITY 9:

TEACHING NOTES:

1. The purpose of this activity is to demonstrate the technique of preparing a diagnostic truth table. Preparation of such a truth table is the first step in designing a computer that will give a possible diagnosis based on a set of clinical findings.

2. Anticipated time: one to two periods.

3. You may wish to point out to the students that in the process of using a truth table (as in Procedure Step 4), they are performing the same function as a computer.

4. An alternate strategy would be to have the students develop the summary statement for each disease (given on pp. 30-31) as they read ST-9.

ANTICIPATED RESULTS:

1. Procedure Steps 1 and 3.

FINDINGS

Diseases	a	b	c	d	e	f	g	h	i	j
Epilepsy (grand mal)	1	0	0	0	0	0	1	0	0	0
Multiple sclerosis	0	1	0	1/0	1/0	0	0	1	0	0
Cerebral hemorrhage	1/0	1	1/0	1/0	0	1/0	1	0	0	0
Cerebral thrombosis	1/0	1	0	0	0	0	1/0	1/0	1/0	0
Brain tumor	1/0	1	1/0	1/0	0	1/0	1/0	1/0	0	1/0

2. Procedure Step 2.

Epilepsy: $a \wedge \bar{b} \wedge \bar{c} \wedge \bar{d} \wedge \bar{e} \wedge \bar{f} \wedge g \wedge \bar{h} \wedge \bar{I} \wedge \bar{j}$ (i.e., convulsions and not continuing brain dysfunction and not blood in CSF...)

Multiple sclerosis: $\bar{a} \wedge b \wedge \bar{c} \wedge \bar{f} \wedge \bar{g} \wedge h \wedge \bar{I} \wedge \bar{j}$

Cerebral hemorrhage: $b \wedge \bar{e} \wedge g \wedge \bar{h} \wedge \bar{I} \wedge \bar{j}$

Cerebral thrombosis: $b \wedge \bar{c} \wedge \bar{d} \wedge \bar{e} \wedge \bar{f} \wedge \bar{j}$

Brain tumor: $b \wedge \bar{e} \wedge \bar{I}$

3. Procedure Step 4--Disease Possibilities

0101010101--brain tumor

1111111111--none of the given diseases

0100001000--cerebral hemorrhage, cerebral thrombosis or brain tumor

LESSON 10: LOGIC GATES

RATIONALE:

This lesson reviews the switching functions of the various logic gates introduced in Biomedical Mathematics and explains the relationships between such gates and the computer. LA-10 provides the background needed for development of a simple diagnostic computer in LA-11.

In LA-10, Part I, the students are introduced to the "brain frame" and identify a series of unknown logic gates by means of truth tables. In Part II the students connect various combinations of INVERT and 2-input gates to create equivalent circuits. Proficiency in this technique is essential for construction of diagnostic computers in Lessons 11 to 13.

OBJECTIVES:

The student will:

- state how logic gates are used in computers.
- give the symbols and the switching functions of the following gates: 2-AND, 2-NOR, 2-OR, 2-NAND and INVERT.
- solve problems involving the construction of equivalent circuits using INVERT and 2-input logic gates.
- point out the following components of a logic gate: input sockets, output socket, light-emitting diode.
- identify an unknown gate by determining the truth table for that gate in the laboratory.

SEQUENCE: ST-10, LA-10

SUGGESTIONS:

1. At some point early in the sequence on computer diagnosis of brain disease, it would be a good idea to discuss computers in general and their role in science and medicine. Among the possibilities you may wish to consider are the following: (a) visiting speaker (a computer programmer, or a medical librarian who could speak about computerized information retrieval, or a hospital administrator who could discuss the impact of computers on hospitals), (b) field trip (to see a computer in action). In addition, you might bring in samples of computer programs or tapes and explain how they are used. Your colleague in Biomedical Mathematics may be able to contribute some background information.

2. You may wish to attack some myths about computers. For example, some laymen blame computers for bad experiences with billings--actually the blame almost always lies with the people who feed the data to or program the computers.

3. If the students find this lesson difficult, they should review Problem Set 5 (p. 25) of Biomedical Mathematics, Unit IV.

4. Problem Set 11 lays a foundation for LA-11. It will be important for students to be able to solve these problems before starting LA-11. You may wish to assign Problem Set 11 as homework.

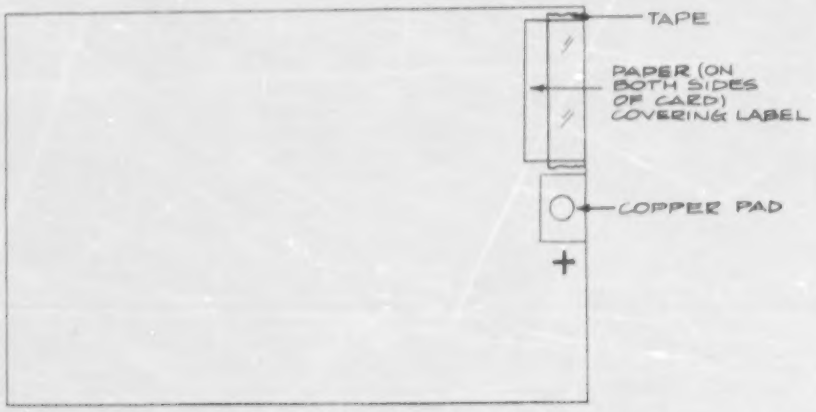
INFORMATION ON LABORATORY ACTIVITY 10:

TEACHING NOTES:

1. The purpose of this activity is to familiarize the students with (a) the nature and operation of logic gates (Part I) and (b) techniques for combining gates to produce new switching functions (Part II). The overall purpose of LA-10 is to bring students closer to the point at which they will be able to design and construct a computer for diagnosing brain disease (LA-13).

2. Anticipated time: one to two periods.

3. Part I calls for "unknown" 2-input cards. Note that the 2-input cards supplied with the BIP have labels on both sides in the same corner. These labels should be temporarily covered, taking care not to damage the paper label or cover the copper pad referred to in the diagram below. (This copper pad makes electrical contact with the terminal (nut and screw) on the brain frame. To cover the labels, use small strips of folded paper, double-folded if necessary. The paper may be taped onto the card as shown in the figure.



UNDERSIDE OF PC CARD SHOWING HOW TO COVER LABEL

4. At the end of the general introduction, there is reference to caution relevant to inserting a wire into a socket. The first insertion is usually difficult to make. It would be helpful to have some 24-gauge piano wire on hand for students to use to work through new sockets prior to attempting to insert BIP wire. If a wire breaks in a socket, it may be possible to remove the wire with tweezers. Also, as mentioned in the introduction, there is a second socket for each input on a card, and these sockets may also be used. (Unfortunately, both sockets are needed in some cases in upcoming activities.)

5. The copper pads on the underside of the PC cards should be shiny. Over a period of time, the copper surfaces may oxidize slightly and take on a dull grayish

appearance. The oxide is a poorer electrical conductor than pure copper and should be removed with fine sandpaper. Only the copper pads that contact the screw connections need be cleaned.

6. In Part I, Step 2, students are told that if a card does not fit properly on a brain frame, they should inform the instructor. It would be good to have ready a needle file for poor fits--very slight filing around the holes in the two copper pads should solve the problem. Another solution that may not be obvious to students is simply to move the card to a different location on the brain frame.

7. In Part I, Step 5, the students are introduced to some techniques of "troubleshooting" the brain frame. If they can't resolve their problems with the suggestions provided, you might also check the underside of the brain frame to make sure that there are no broken wires. Check especially the regions where the wires wrap around the heads of screws. Another possible problem could be that the BIP is not providing sufficient voltage (i.e., 5 volts). This can be checked with a volt-ohmmeter as explained in the BIP Manual.

Additional information on troubleshooting is provided after the Materials List.

MATERIALS: (for 10 set-ups)

10 BIP's
10 brain frames (with thumb nuts)
10 pulser cards
wire
2 or 3 wire cutter-strippers
40 unknown cards (with labels covered)
10 2-NAND cards
10 2-NOR cards
10 2-OR cards
10 2-AND cards

TROUBLESHOOTING THE BRAIN FRAME:

There are a number of ways in which the gate cards may be damaged. Here are some of the things to watch out for.

Problem 1. Bending of the socket pins. This can happen while trying to insert a lead if too much force is applied in any direction other than straight down. (Solution: A bent socket pin can often be bent back into its original position and still function. If the straightened pin will not accept a lead, it is possible to achieve adequate contact by stripping about 10 to 12 mm of insulation from the end of a lead and wrapping the wire tightly around the outside of the pin.

Problem 2. Permanently occluded socket with a broken-off piece of wire that is too short to remove. This should not occur unless the wire is nicked--a result of careless use of the cutter-strippers. (Solution: To replace socket pins, refer to Section 7 of the BIP Manual. Replacement pins are provided as BIP accessories. After removing a bad pin, a new pin may be attached to a PC card by use of a light soldering iron.)

Problem 3. Card installed backwards. (Solution: Reverse the card and test all gates on the card to see whether they still provide the correct truth tables.)

Problem 4. Reversed leads to the BIP. (Solution: Correct the problem and test all cards in the frame at the time, as in #3.)

Problem 5. Improper voltage supplied to the brain frame. This can occur if the BIP is programmed incorrectly and may create erratic and/or wrong truth tables, popping, smoking and heating up of the IC chips. The housings of the IC chips should never feel warm or hot. (Solution: Correct the programming and test all cards as in #4.)

Problem 6. Two different signals (+ and 0) fed into the two sockets of one input. This will cause the IC housings to overheat. The smell of burning plastic indicates that this is happening. (Solution: Disconnect the power supply to the brain frame immediately. Check the wiring to all cards. Recheck all cards to see if they will still function as in #4. All damaged or malfunctioning cards should be returned to the Biomedical Project. In most cases they can be repaired.)

Problem 7. Flickering diode lights on a single card. (Solution: Check the two thumb nuts to make sure they are tight. Also the copper pads may need sanding as described in Teaching Note 5.)

ANTICIPATED RESULTS:

PART I:

The student will identify the unknown gates.

PART II:

In Problem Set 11, Part I, the students prepare a table that answers the questions in Part II. See Key in the next lesson.

ANSWERS TO DISCUSSION QUESTIONS:

1. If the card is installed backwards, it may be damaged.

2. 4 LED's, 1 housing, 16 input sockets, 4 output sockets.

3. Pulser cards contain switches (gate cards do not); each pulser has two LED's and two output sockets rather than one.

LESSON 11: A SIMPLE DIAGNOSTIC COMPUTER

RATIONALE:

This lesson introduces two modifications in circuitry design that will be useful in the construction of the diagnostic computer for brain disease. The first of these is the design of individual disease circuits to yield an output of 0 rather than 1. This is done so that an INVERT card may be used to record all the diagnostic outputs. Secondly, the circuitry is modified to conserve on the number of INVERT gates used. The students then incorporate these modifications into a simple diagnostic computer based on three findings and two diseases. The goal of this activity is to provide experience in the design and construction of a simple diagnostic computer before the students construct the diagnostic computer for brain diseases in LA-13.

Problem Set 11 was designed to (a) review the symbolic logic that corresponds to LA-10, Part II and (b) give the students some practice at designing circuitry when presented with logic statements. This review should prepare the students adequately for the design and construction of a simple diagnostic computer in LA-11.

OBJECTIVES:

The student will:

- state the reason for routing each disease circuit through a final INVERT gate.
- construct a simple diagnostic computer and test it.

SEQUENCE: Problem Set 11; LA-11

KEY--PROBLEM SET 11:

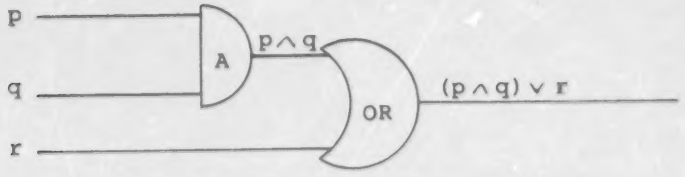
PART I:

2-INPUT GATES AND SWITCHING FUNCTIONS

OUTPUT	$p \wedge q$ AND	$\overline{p \wedge q}$ NAND	$p \vee q$ OR	$\overline{p \vee q}$ NOR
WITH OUTPUT INVERTED	$\overline{p \wedge q}$ NAND	$\overline{\overline{p \wedge q}} = p \wedge q$ AND	$\overline{p \vee q}$ NOR	$\overline{\overline{p \vee q}} = p \vee q$ OR
WITH BOTH INPUTS INVERTED	$\bar{p} \wedge \bar{q}$ $= \overline{p \vee q}$ NOR	$\overline{\bar{p} \wedge \bar{q}} = \bar{\bar{p}} \vee \bar{\bar{q}}$ $= p \vee q$ OR	$\bar{p} \vee \bar{q}$ $= \overline{p \wedge q}$ NAND	$\overline{\bar{p} \vee \bar{q}}$ $= \bar{\bar{p}} \wedge \bar{\bar{q}}$ $= p \wedge q$ AND
WITH BOTH INPUTS INVERTED AND OUTPUT INVERTED	$\overline{\bar{p} \wedge \bar{q}}$ $= \bar{\bar{p}} \vee \bar{\bar{q}}$ $= p \vee q$ OR	$\overline{\overline{\bar{p} \wedge \bar{q}}} = \bar{p} \wedge \bar{q}$ $= \overline{p \vee q}$ NOR	$\overline{\bar{p} \vee \bar{q}}$ $= \bar{\bar{p}} \wedge \bar{\bar{q}}$ $= p \wedge q$ AND	$\overline{\overline{\bar{p} \vee \bar{q}}}$ $= \bar{p} \vee \bar{q}$ $= \overline{p \wedge q}$ NAND

PART II:

1.



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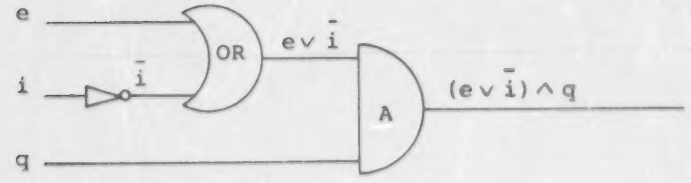

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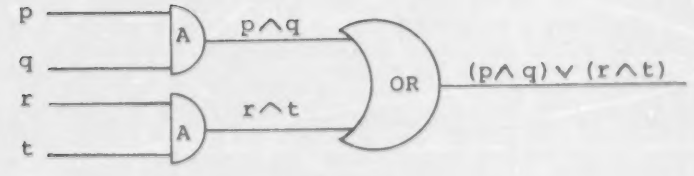

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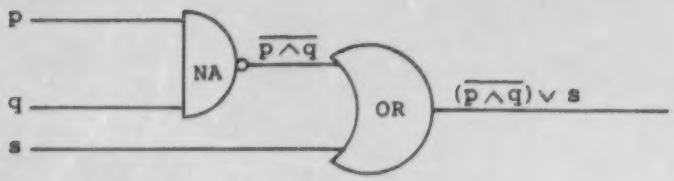

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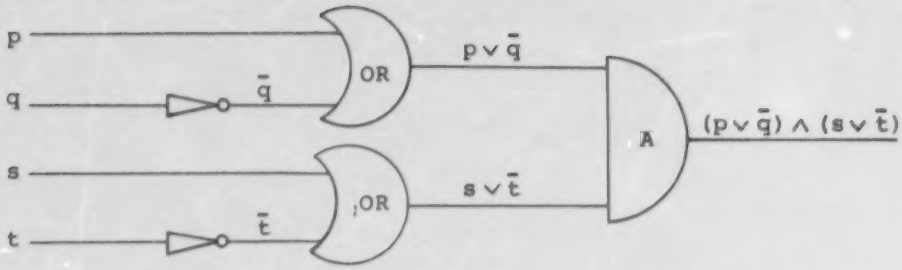
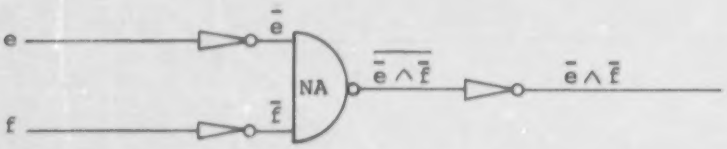


6.

7.

8.



INFORMATION ON LABORATORY ACTIVITY 11

TEACHING NOTES:

1. The purpose of this activity is to take the students one step at a time through the processes involved in designing and constructing a simple diagnostic computer. This activity prepares the students for LA-13, in which they construct the more complex diagnostic computer for brain disease.

2. Anticipated time: one to two periods.

3. In Step 5 of the Procedure the students are told that the extra input socket of a gate can be used to carry the original input to anywhere they need it. It is

important that the students understand how this is done. Since the particular circuit that they will be working with in this activity does not require duplicate inputs, it might be a good idea to give them a concrete example at this time so that when they need the technique in LA-13, it will be familiar. One example that you might use is shown below. (Note: the example is hypothetical and does not correspond to an actual disease.)

Example:

Suppose that we were to add a third disease to the truth table already given for cold and strep throat. We will call the new disease "mountain fever." Mountain fever is characterized by the presence of sniffles (finding p) and fever (finding q) and may or may not involve a sore throat (finding r). The composite truth table for all three diseases is shown below.

FINDINGS			POSSIBLE DIAGNOSES
sniffles p	fever q	sore throat r	
1	0	1/0	cold
1/0	1/0	1	strep
1	1	1/0	"mountain fever"

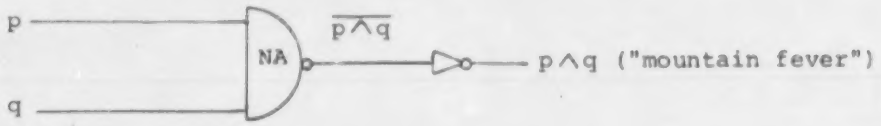
The corresponding logic statement for each diseases is:

cold: $p \wedge \bar{q}$

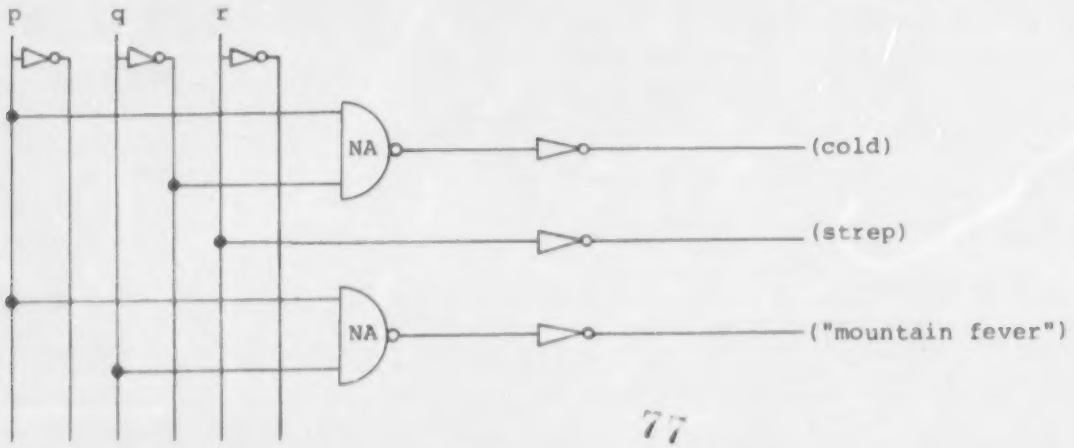
strep: r

"mountain fever": $p \wedge q$

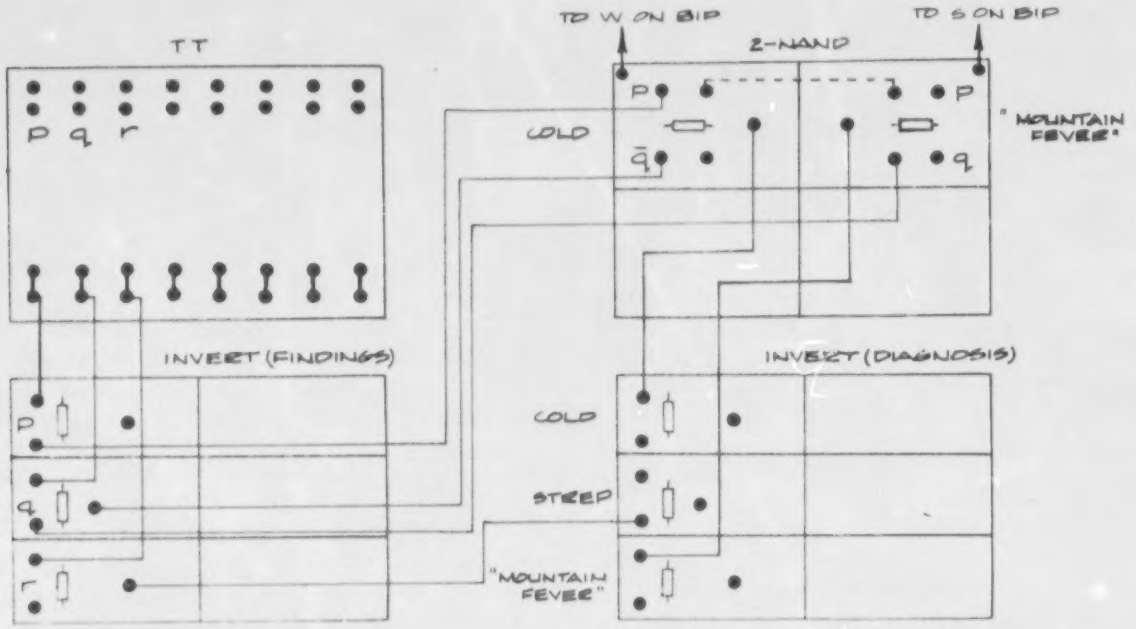
One possible circuit for "mountain fever" is:



The complete circuit diagram for all three diseases now looks like:

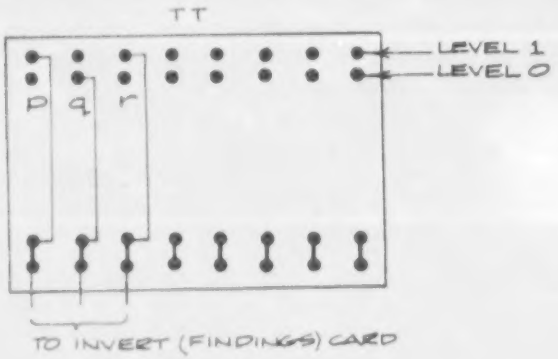


The actual wiring on the brain frame for all three diseases would be as shown in the schematic below. Note that we cannot route the finding p from the INVERT gate to the NAND gate we are using for "mountain fever" because we have already used the second input socket of the INVERT gate to route p to the NAND gate used for the cold circuit. However, the input socket on the NAND gate for "cold" has an alternate socket which we can use. Thus, to obtain the p input for the "mountain fever" NAND gate, we may run a wire from the alternate input socket used for p on the "cold" gate to the input socket we have chosen to receive the p input on the "mountain fever" gate (see broken line in the diagram). If a fourth disease were included that also required a p input, it could be obtained from the second "p" socket of the 2-NAND gate for "mountain fever."



4. In Step 13 of the Procedure the students are told to "plug the p lead into the 1 socket and the q lead into the 0 socket." To do this, they will need to cut pieces of wire and make the connections shown in the diagram below. This is also necessary in Step 16 when they are told to "test the strep circuit by plugging the r lead on the TT card into the 1 socket." (This connection is also shown below.) Since no diagram showing these connections was included in the text, it is possible that the students will be confused when they reach these steps. If this is the case, you might want to draw the diagram shown below on the chalkboard.

5. In Steps 13 and 16 the students test their cold and strep circuits to see whether the LED on the diagnosis card lights up when the appropriate inputs are present. A complete circuit check would require a demonstration that the LED remains off for all other possible combinations of inputs. This point should be brought out to the class. In this activity, an examination of the truth table produced in Step 17 will reveal any errors in wiring.



MATERIALS: (for 10 set-ups)

- 10 BIP's
- 10 brain frames (with thumb nuts)
- 10 2-NAND cards
- 2 or 3 wire cutter-strippers (Xcelite Model 103-S with springs--or equivalent)
- 20 INVERT cards
- 10 TRUTH TABLE cards
- wire

ANTICIPATED RESULTS:

TRUTH TABLE

FINDINGS			POSSIBLE DIAGNOSES
p	q	r	
1	1	1	strep
1	1	0	neither
1	0	1	cold or strep
1	0	0	cold
0	1	1	strep
0	1	0	neither
0	0	1	strep
0	0	0	neither

LESSON 12: (A) SIMPLIFYING THE DIAGNOSTIC TRUTH TABLE

(B) 4-, 6- and 8-NAND GATES

RATIONALE:

In Activity 12A the students simplify their original truth tables for brain disease by discarding findings that are not useful in distinguishing between the different diseases. This is necessary to reduce the number of findings to 8, the maximum number the TRUTH TABLE card can handle. The simplified truth table they arrive at will be used in Activity 13A for designing the circuitry of the diagnostic computer.

LA-12B introduces the students to three new types of logic gates, the 4-, 6- and 8-NAND, which will be very useful in the design of the diagnostic computer. Practice at creating circuits equivalent to 4-NAND and 6-NAND gates from 2-input and INVERT gates is also an important part of this activity.

OBJECTIVES:

The student will:

- produce a simplified diagnostic truth table for brain disease showing 8 finding inputs and 5 disease outputs.
- write the truth tables for the following gates: 4-NAND, 6-NAND, and 8-NAND.
- solve problems requiring the construction of circuits equivalent to 4-NAND and 6-NAND gates using 2-input and INVERT gates.

SEQUENCE: Activity 12A; LA-12B

INFORMATION ON ACTIVITY 12A:

TEACHING NOTES:

1. The purpose of this activity is to arrive at truth tables for brain disease that can be used as a basis for the design of the brain-disease computer.

2. Anticipated time: one period.

3. Since the results of this activity will be used in setting up the final computer, the students who will work together then should cooperate during this activity.

4. The degree of control you exercise over the final set of truth tables is entirely up to you. Although it will be necessary for the members of a single group to agree on the truth tables, it is not necessary that the different groups agree. Clearly, if the truth tables used to design the circuits are in error, the resulting computer will diagnose incorrectly. On the other hand, the remainder of the task might be considered a test of the ability of a group to construct a computer that correctly reflects the truth tables with which they started.

5. Although this activity is designed to reduce the number of findings to eight, our sample results which follow indicate that there are nine findings which have some diagnostic value. If you happen to have a group composed of electronic geniuses, you might present them with the special challenge of designing and constructing a nine-finding computer for the five diseases. The ninth input can be provided by a pulser. Otherwise, the nine-finding computer can be built using the same cards that will be available for the eight-finding computer.

6. Generally speaking, the fewer the number of findings, the easier it is to design and build the computer. You might consider further limiting the number of symptoms (below eight) for students who are experiencing difficulty.

7. It may not necessarily be obvious what selection of findings is optimum.

The direct effect of a single finding can be assessed; but the interactions among findings aren't always easy to recognize. For example, if two findings with the same truth values always go together, one is superfluous; but if they can vary independently, both columns may perhaps appropriately be retained. In the sample truth table shown below findings c and f are an example of independent variation.

8. You may wish to point out that there are times when a 1/0 entry in a truth table may be of value. For example, suppose you have a finding "x" with a value of 1/0 for disease #1 and a value of 0 for disease #2. When finding "x" is present (x=1), disease #2 is ruled out. However, when x=0 the two diseases cannot be distinguished. Thus, 1/0 entries may prove helpful under some circumstances even though they do not always permit one to distinguish between two diseases.

9. Note that there is no combination of the ten findings that will uniquely point to a diagnosis of cerebral hemorrhage.

SAMPLE RESULTS:

The complete truth table from Lesson 9 is reproduced here for easy reference.

FINDINGS

Diseases	a	b	c	d	e	f	g	h	i	j
Epilepsy (grand mal)	1	0	0	0	0	0	1	0	0	0
Multiple sclerosis	0	1	0	1/0	1/0	0	0	1	0	0
Cerebral hemorrhage	1/0	1	1/0	1/0	0	1/0	1	0	0	0
Cerebral thrombosis	1/0	1	0	0	0	0	1/0	1/0	1/0	0
Brain tumor	1/0	1	1/0	1/0	0	1/0	1/0	1/0	0	1/0

The following analysis of findings might be made.

a. This finding is of marginal usefulness in reducing the possibilities. A value of 1 rules out only MS, a value of 0 rules out only epilepsy.

b. A useful finding for diagnosing epilepsy: a 0 rules out the other four diseases.

c. Useful: a 1 rules out epilepsy, MS and cerebral thrombosis.

d. Of marginal value: a 1 rules out epilepsy and cerebral thrombosis.

e. Useful: a 1 rules out all but MS.

f. Useful: a 1 rules out epilepsy, MS and cerebral thrombosis.

g. Useful: a 1 rules out MS; a 0, epilepsy and cerebral hemorrhage.

h. This finding (slow onset) is redundant. With but one exception, the finding in this column must be the opposite of the "g" finding (rapid onset). The exception is g=0 and h=0, which has the same meaning as a 1 in the "i" column (progressive onset).

i. Useful: rules out all but cerebral thrombosis when 1.

j. Useful: rules out all but brain tumor when 1.

Thus nine of the original ten findings appear to have at least some usefulness. Of the nine remaining, findings "a" and "d" appear to be the least useful. One of these two should be eliminated. (In all of the remaining sample results given in this sequence, it will be assumed that findings "a" and "h" have been eliminated.)

INFORMATION ON LABORATORY ACTIVITY 12B:

TEACHING NOTES:

1. The purpose of this activity is (a) to acquaint the students with the use of 4-, 6- and 8-NAND gates which are necessary for LA-13, and (b) to give the students practice in developing alternate circuits for 4-NAND and 6-NAND gates using combinations of various 2-input and INVERT gates.

2. Anticipated time: one to two periods.

3. Throughout this sequence of activities for developing the diagnostic computer we have emphasized the importance of having the students develop proficiency in designing alternate circuits. Part II of this activity once again deals with this technique in relation to 4-NAND and 6-NAND gates. It is necessary that the students understand this activity and be able to complete it successfully before they proceed to Activity 13A in which they will design the circuitry for the diagnostic computer.

4. In Part II when the examples are given, symbolic logic is used to determine the necessary circuitry. The solution is then checked out using truth values of 1 and 0 to determine whether the circuitry will indeed give the desired output. If some students are confused by the symbolic logic statements you might try approaching the problems using truth values of 1 and 0 in conjunction with the truth tables for the various gates to solve the problems. This approach may be easier for some students to grasp. The distinctive feature of a NAND gate is that an output of 0 occurs only when all inputs (whatever the number) are 1. Thus an alternate approach to the design of "NANDing" circuits is to find combinations of gates that give an output of 0 only when all inputs are 1.

MATERIALS: (for 10 set-ups)

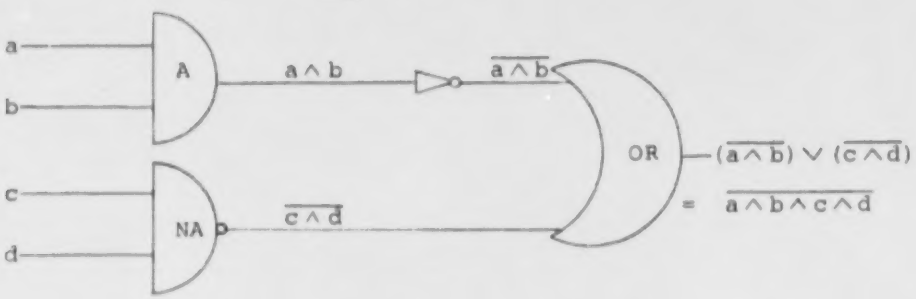
10 BIP's	10 4-NAND cards	10 2-NOR cards
10 brain frames	10 8-NAND cards	10 2-NAND cards
10 TT cards	10 2-AND cards	wire
30 INVERT cards	10 2-OR cards	2 to 3 wire cutter-strippers

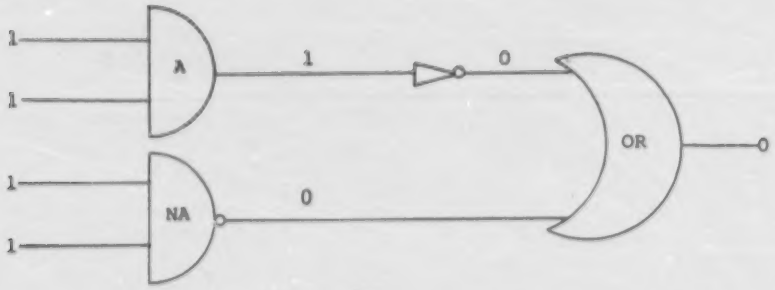
ANTICIPATED RESULTS:

Part I: Students should find that the LED's on the 4-, 6- and 8-NAND gates only go out (indicating an output of 0) when all the inputs to the gates are at level 1.

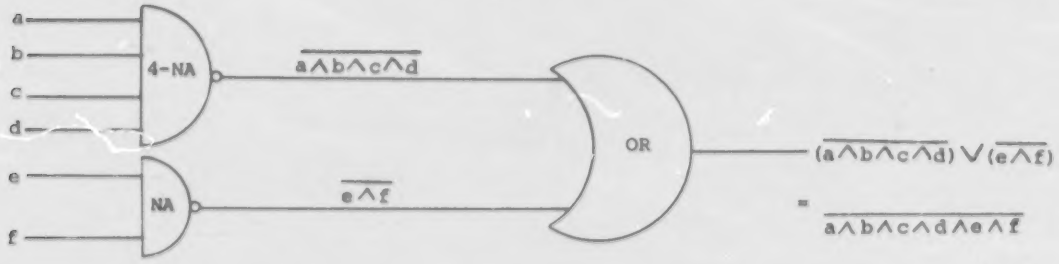
Part II:

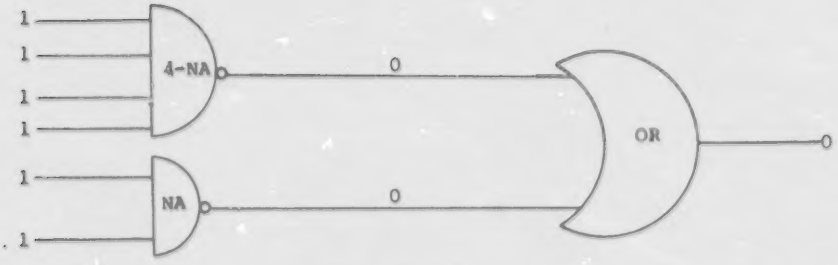
Problem #1: An OR gate will furnish the appropriate output. However, it is also necessary to invert the output of the AND gate ($a \wedge b$) in order to provide an input of $\overline{a \wedge b}$ to the OR gate. The same circuit with truth values of 1 and 0 is also shown.



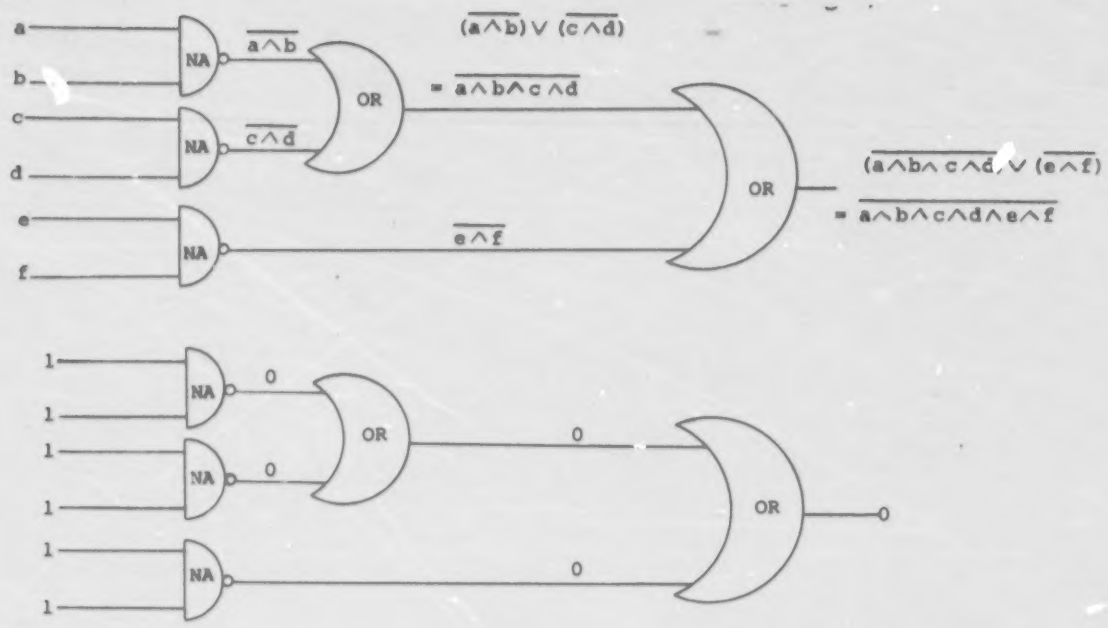


Problem #2: Since the final output of $(\overline{a \wedge b \wedge c \wedge d}) \vee (\overline{e \wedge f})$ is indicative of a 2-OR gate, the 4-NAND and 2-NAND will be used to provide the initial outputs of $\overline{a \wedge b \wedge c \wedge d}$ and $\overline{e \wedge f}$. These outputs are then fed into the 2-OR gate to give the final desired output.





Problem #3:



LESSON 13: (A) DESIGNING THE CIRCUITRY FOR THE DIAGNOSTIC COMPUTER

(B) CONSTRUCTING THE DIAGNOSTIC COMPUTER

(C) REVIEW

RATIONALE:

In Activity 13A the students use the simplified truth table for brain disease obtained in Activity 12A to design the circuitry for their diagnostic computers. Once they have designed the circuitry on paper, they then proceed to the construction of the computer in LA-13B. This lesson completes the sequence on symbolic logic and its application to the design and construction of a computer for diagnosing brain diseases.

OBJECTIVES:

The student will:

- design the circuitry for a diagnostic computer for brain disease, using the simplified truth table arrived at in Activity 12A.
- construct the diagnostic computer using the circuit diagram completed in Activity 13A.
- test the diagnostic computer by inputting various combinations of findings and noting the possible diagnoses that result.

SEQUENCE: Activity 13A; LA-13B; Demonstration 13; Review Set 13

SUGGESTIONS:

1. Since the completed computer represents a considerable investment of time and effort on the part of the students, it is recommended that they be allowed a significant amount of time to operate it before being required to dismantle the apparatus. The students might also be asked to review the five brain-disease case histories to see whether their computers provide the correct diagnoses.

2. Note that Demonstration 13, which follows, requires a brain frame. To avoid the necessity of having one student group dismantle their computer in order for the demonstration to be set up, it is advisable to have one extra brain frame on hand.

INFORMATION ON ACTIVITY 13A AND LABOPATORY ACTIVITY 13B:

TEACHING NOTES:

1. The purpose of this activity is to design the appropriate circuits for the brain-disease computers and to use these circuits to construct the diagnostic computers.

2. Anticipated time: three to four periods.

3. It is important that the supply of logic gates available to each student group be limited to the quantities indicated in the student procedure. The additional cards in your possession (which will be needed for activities in future units) should not be accessible to the students except as replacements for malfunctioning or damaged cards. The purpose of this limitation is to require that the students make at least some use of their knowledge of symbolic logic to design and construct alternate circuits. The amount of ingenuity needed is not excessive. If the students have successfully completed LA-10 and LA-12B, they should have little difficulty in developing the alternate circuits needed.

4. You may wish to point out that it would be a good idea to reserve one INVERT card exclusively for the diagnosis outputs. This would leave 12 other INVERT gates, eight of which must be used to invert findings. Thus there would be only four INVERT gates remaining to be used in combinations that simulate NAND gates.

5. In order to increase the chance of success in LA-13B, you may wish to have each group check their final circuit diagram with you.

6. When wiring the diagnostic computer in LA-13B it is essential that the students be accurate in tracing down the inputs that they need to route to each disease circuit. A specific example of how to use the alternate input socket on one gate to route a desired finding input to another gate was given in the Teaching Notes for LA-11. You may wish to review this technique before allowing the students to proceed with the construction of the computer.

7. If the students test each disease circuit as they proceed (as described in the procedure), the computer should function properly when completed. If it fails to do so, the first thing to look for is a wire that has come out of its socket. Should a group end up with a computer that diagnoses properly for all but one disease, the circuit for that disease should be traced out and re-checked. If more than one circuit is questionable, the quickest approach may be to start over from the beginning.

8. Technique is important in wiring the computers. Encourage the students to proceed in a methodical, neat and careful manner. In most cases, the reason for faulty diagnoses will be wiring errors.

MATERIALS: (for 10 set-ups)

- 10 BIP's
- 10 brain frames
- 30 INVERT cards
- 10 2-AND cards
- 10 2-OR cards
- 10 2-NOR cards
- 10 2-NAND cards
- 10 4-NAND cards
- 10 8-NAND cards
- 10 TRUTH TABLE cards
- wire
- 2 to 3 wire cutter-strippers

ANTICIPATED RESULTS:

Activity 13A:

For any specific truth table there will be a variety of circuits that will serve. The sample circuit diagram on page is based on the sample truth table from

Activity 12A with finding "a" removed to reduce the number of findings to eight. Note that additional OR gates could have been formed by following NOR gates with INVERT gates. Or an AND gate could have been formed by preceding one of the NOR gates with two INVERT gates. Note that in the "brain tumor" circuit shown, findings e and i are inverted twice before they reach the first OR gate. Two INVERT gates could have been saved by taking e and i directly to the first OR gate, instead of inverting $\bar{e}$ and $\bar{i}$. The third INVERT gate could have been saved as well by routing $\bar{b}$ (instead of b) directly to the second OR gate.

LABORATORY ACTIVITY 13B:

Some groups may decide that they can discover no set of findings that uniquely points to one or another of the diseases. (In our sample, this is the case with cerebral hemorrhage.) Or they may find that several different sets of findings give the same unique diagnosis. If the computer has been constructed properly, these outcomes will depend upon the nature of the truth tables used to design the computer.

Some diagnoses may be found that are not all that obvious from an examination of the truth tables. In our sample it was anticipated, for example, that a positive skull X-ray would be needed to point to brain tumor alone. However, 11000000, which involves a negative skull X-ray, also uniquely spells tumor.

Since there are two possibilities for each of the eight findings, 2^8 or 256 different combinations are possible. Presumably the students will not have time to check them all.

A map of the brain-frame set-up used for the sample circuit is included.

DEMONSTRATION 13:

ELECTRONIC SEARCHING FOR BRAIN DISEASES

INTRODUCTION:

Once the students have created their brain-disease computers, they will be able to check various combinations of findings to see what diseases are diagnosed. It is unlikely, however, that they will have the persistence to check all 256 possible combinations of findings. The apparatus described here, when connected to a brain-disease computer, will input the full succession of possible findings at time intervals of your choosing.

The apparatus makes use of a TIMER card and a number of FLIP-FLOP cards. These devices will be used by the students later in the course, when their operation will be explained. For the present it is enough to know that the timer has an output that consists of a succession of voltage pulses, and the flip-flops respond to these pulses by changing output from level 0 to level 1 or vice versa with each pulse.

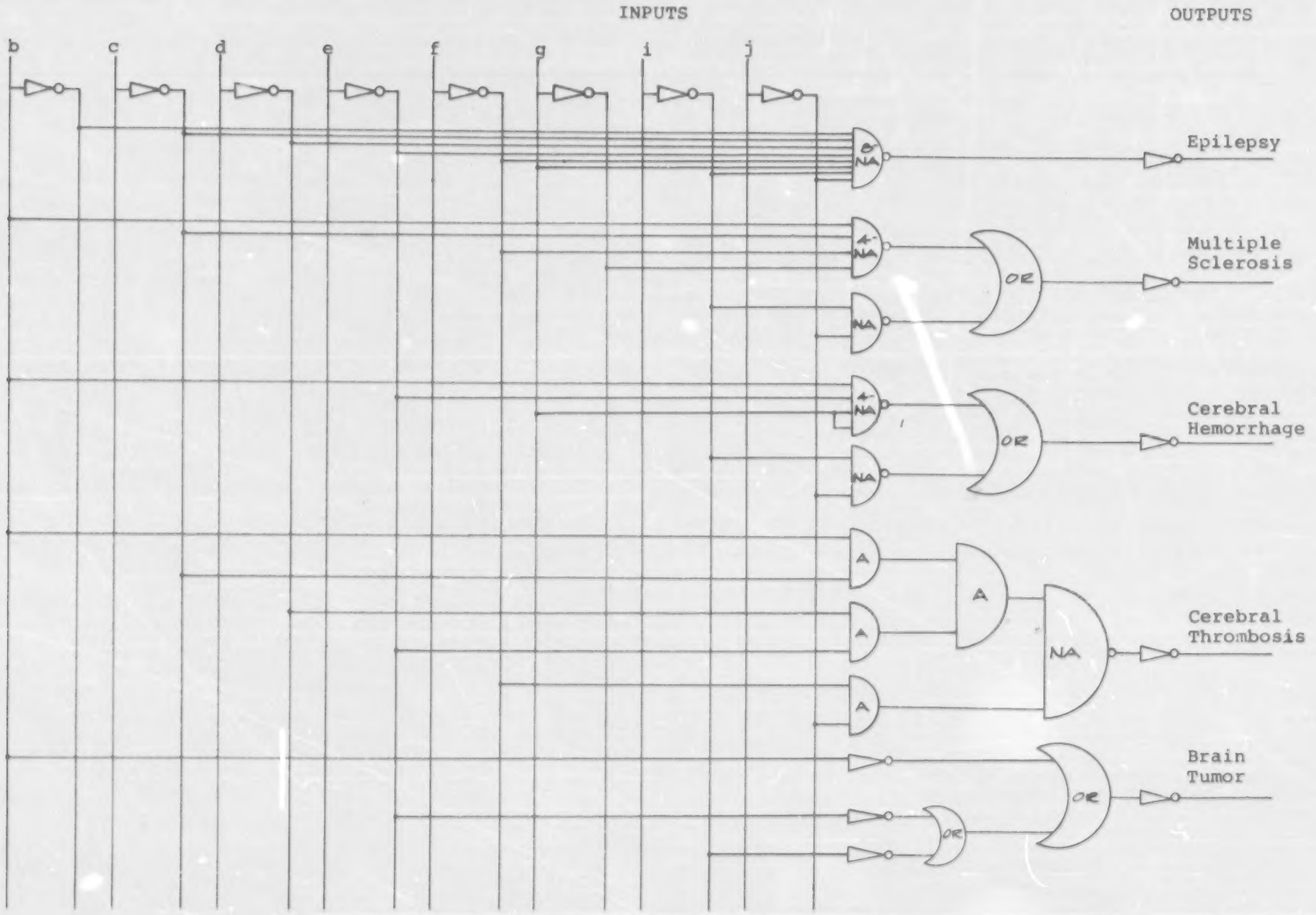
The output of the timer is fed to the input of one flip-flop, the output of that flip-flop to the input of the next, and so on. With such a set-up, outputs of the flip-flops will then change in a manner that gives all possible combinations of outputs. In essence, they perform a binary counting sequence.

If you have one or more proficient students (who, for example, complete their computer ahead of the remainder of the class), you may wish to assign the construction of the apparatus to them as a special project.

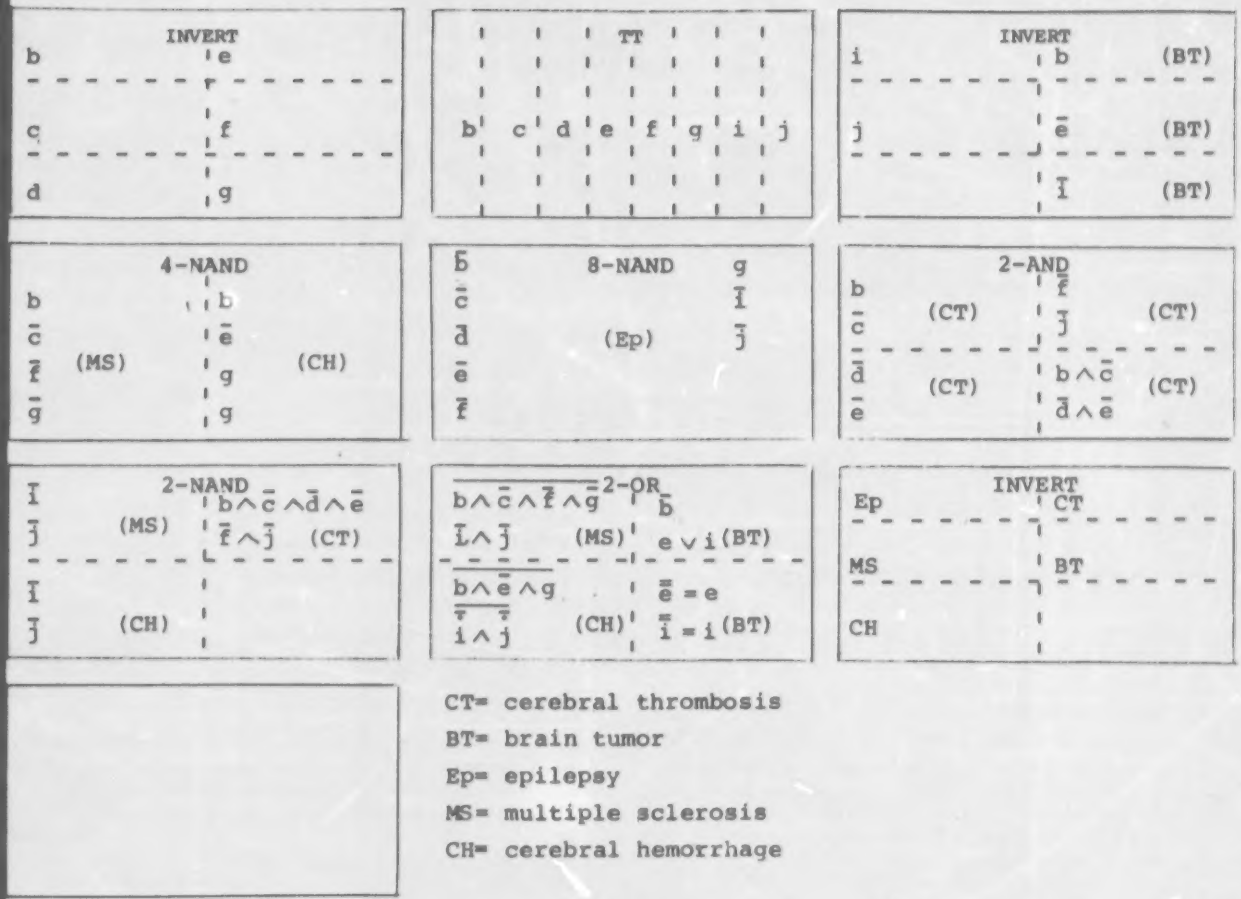
MATERIALS:

- brain frame
- TIMER card
- 4 JK-FF cards
- 8-NAND card
- 2-NAND card
- PULSER card
- wire
- wire cutter-strippers

SAMPLE CIRCUIT DIAGRAM



SAMPLE BRAIN-FRAME MAP



CT= cerebral thrombosis
BT= brain tumor
Ep= epilepsy
MS= multiple sclerosis
CH= cerebral hemorrhage

PREPARATION:

1. Install four FLIP-FLOP cards on the brain frame (+ on right). Three of them should be located in the second row, the fourth in the upper left corner.

2. Install (+ on right) the TIMER card at row 3, column 3 (i.e., immediately below the FLIP-FLOP card that is farthest to the right).

3. Make the following connections on the timer card.

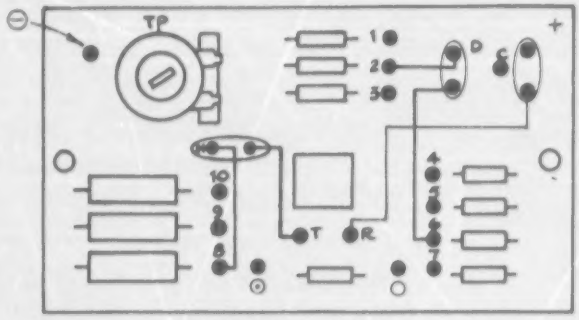
R to either +

T to either H

#8 to the remaining H socket

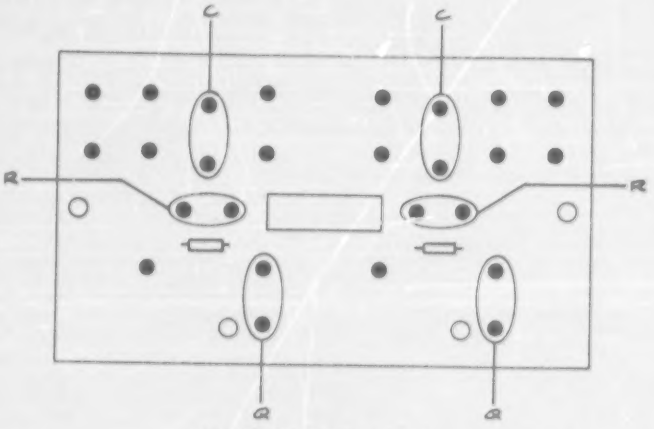
#6 to either D

#2 to the remaining D socket



TIMER CARD

4. Note that each FLIP-FLOP card has two FLIP-FLOP gates. The two input sockets (C) for each gate are easily recognizable, being slightly below the other three pairs of sockets near the top of the card. As with other logic gates, the two input sockets are electrically the same. The output (Q) of the FLIP-FLOP gate also consists of two sockets which are electrically the same. These are located near the diode.



FLIP-FLOP CARD

5. Note that the TIMER card has two outputs near the bottom of the card, labeled "0" and "0." Connect the timer output 0 to either input socket (C) of the FLIP-FLOP gate on the extreme right.

6. Connect one output socket (Q) of this FLIP-FLOP gate to one of the input sockets (C) of the FLIP-FLOP gate on the left side of the same card.

7. Connect the output of the last mentioned FLIP-FLOP gate to the input of the FLIP-FLOP gate immediately to the left. (In this case, the next gate will be on the second FLIP-FLOP card.) Continue in this fashion until you reach the left edge of the frame. Then connect the output of the FLIP-FLOP gate at the far left to the input of the rightmost FLIP-FLOP gate in the top row. Again continue wiring to the left. The last FLIP-FLOP gate should have no connection to its output (for the moment).

8. Test this part of the set-up by connecting it to a BIP. Program the BIP as follows.

T to X

S to one of the two + (plus) sockets in the upper-right corner of the TIMER card

W to the - (minus) socket in the upper-left corner of the TIMER card

9. Plug in the BIP. (Note: if you are unfamiliar with the binary system, the remainder of this step may seem somewhat confusing. A discussion with the Mathematics instructor should clear up any difficulties. The diodes of the FLIP-FLOP gates should turn on and off in binary sequence, if read from left to right starting with the card in the top row and continuing with the cards in the second

row. A lit diode represents "1" and an unlit diode represents "0." For example, a count of 00000011 corresponds to the situation in which all the diodes are off except the two at the extreme right. The beginning of the counting sequence should appear as follows.

00000000	(=0)	00001010
00000001	(=1)	00001011
00000010	(=2)	00001100
00000011	(etc.)	00001101
00000100		00001110
00000101		00001111
00000110		00010000
00000111		00010001
00001000		00010010
00001001		00010011 (=19)

The counting sequence will continue until all eight diodes are lit simultaneously. At this point the count will be

$$11111111 = 2^7 + 2^6 + 2^5 + 2^4 + 2^3 + 2^2 + 2^1 + 2^0$$

$$= 128 + 64 + 32 + 16 + 8 + 4 + 2 + 1$$

$$= 255$$

On the next count all the diodes will go off and the sequence will begin over again from zero. The students should be familiar with counting in the binary (base 2) system from earlier courses in mathematics, and you may wish to demonstrate this aspect of the set-up before continuing.

10. Note that the timer setting specified in Step 3 provides a rather slow count. During the demonstration it will be useful to increase the counting frequency. There are four ways in which to vary the frequency with which pulses are delivered to the FLIP-FLOP gates. You should experiment with the following adjustments to familiarize yourself with the TIMER card.

a. The wire to #8 may alternatively be run to #9 or #10. #9 provides 10 times the frequency of #8, and #10 provides 100 times the frequency of #8.

b. The wire to #6 may alternatively be run to #4, #5 or #7. These changes, however, will cause only small changes in the frequency.

c. The wire to #2 may alternatively be run to #1 or #3. #3 will provide a frequency about half that provided by #2. #1 will increase the frequency by varying amounts. (See d below.)

d. The blue potentiometer in the upper-left corner of the TIMER card may be rotated (either with the fingers or a small screwdriver). Clockwise rotation increases the frequency, while counterclockwise rotation decreases it. The degree of change in the frequency varies, depending upon whether socket #1, #2 or #3 is in use. The effect is greatest when socket #1 is in use. The complete range of available frequencies runs from about 50,000 pulses per second (using #1, #4 and #10 with the potentiometer rotated fully clockwise) to about one pulse every five seconds (using #3, #7 and #8 with the potentiometer rotated fully counterclockwise).

11. To stop the count at any particular point, disconnect the lead to #4 (or #5 or #6 or #7, depending upon which is in use) on the TIMER card. When the lead is reconnected, the count will resume where it left off.

12. One way to restart the counting sequence at 0 is as follows. First disconnect the TIMER as in Step 11. Take a free wire and plug it into the socket in the upper-left corner of a FLIP-FLOP card. Then, moving from right to left, touch the free end of the wire to one of the reset (R) sockets on each FLIP-FLOP that has

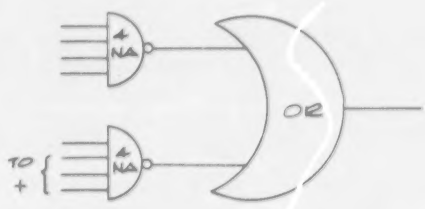
a diode lit. After you have finished experimenting with the counter, unplug the BIP and continue.

13. Install on the "counting" frame an 8-NAND card, a 2-NAND card and a PULSER card. (If all 8-NAND cards are in use, a 4-NAND card and a 2-OR card may be substituted.)

14. Remove the lead connecting the output of the TIMER to the first FLIP-FLOP gate. (If you have substituted 4-NAND and 2-OR cards for the 8-NAND card, omit Step 15.)

15. Connect three inputs of the 8-NAND gate to the plus socket in the upper-right co ner of the card (e.g., p to q, q to r, and r to +). The other five inputs will be connected later to the student computers. Omit Step 16.

16. Make an 8-NANDing circuit out of two 4-NAND gates and a 2-OR gate as shown in the diagram. Connect three inputs of one 4-NAND gate to the plus socket in the upper right corner of the 4-NAND card (e.g., p to q, q to r, and r to +). The remaining five inputs to the 8-NANDing circuit will be connected later to the student computers.

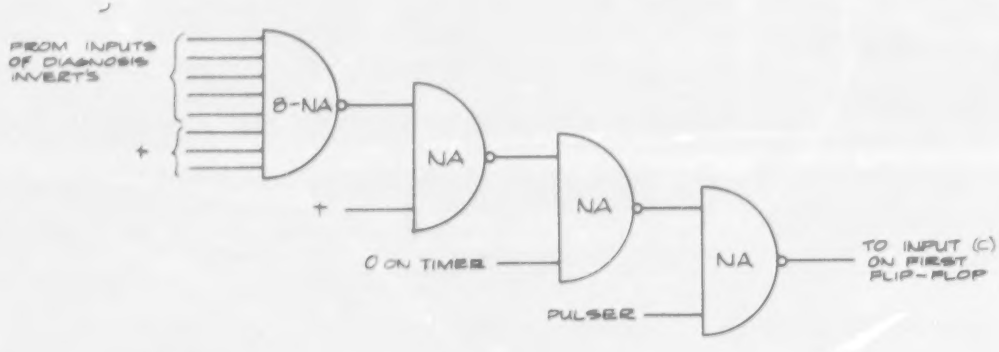


17. Connect the output of the 8-NAND gate to one input of a 2-NAND gate. Connect the other input of the 2-NAND gate to the + socket on the 2-NAND card.

18. Connect the output of the 2-NAND gate used in Step 17 to one input of a second 2-NAND gate. Connect the other input of the second 2-NAND gate to the TIMER output (0).

19. Connect the output of the second 2-NAND gate to one input of a third 2-NAND gate. Connect the other input of the third 2-NAND gate to a pulser. Put the pulser switch on the same side as the input lead to the third 2-NAND gate. (In other words, make this input to the 2-NAND gate a "1.")

20. Connect the output of the third 2-NAND gate to the input of the first FLIP-FLOP gate.



21. Connect eight leads to the outputs (Q) of the eight FLIP-FLOP gates. (Note that the FLIP-FLOP gate at the upper left has <u>two</u> available output sockets. Use either one.) The leads should be long enough to reach the TRUTH TABLE on a student brain frame.

22. The assembled apparatus (counting frame) is now ready to be connected to a student computer. When these connections are made, the device will run through all possible combinations of findings and stop its search whenever a possible diagnosis is indicated on the diagnosis INVERT card.

PROCEDURE:

1. Place the counting frame next to a student brain-disease computer. Connect + on the TIMER card to any convenient + socket on the student frame. Connect - on the TIMER card to any - socket on the student frame. (One BIP will power both frames.)

2. Remove the wires from the third row of the TRUTH TABLE card on the student frame. Connect the outputs (Q) of the right FLIP-FLOP gates (from Step 21 of Preparation) to the third-row sockets in sequence. The order, from left to right, should be the same as on the TRUTH TABLE card. E.g., if the TRUTH TABLE inputs run "abcdefgh" the "a" FLIP-FLOP gate should be the one in the upper-left corner and the "h" FLIP-FLOP gate should be the one at the far right of the second row of cards (the one which is connected to the TIMER card and begins the counting sequence). Thus the very first count, 00000001, should be equivalent to h = 1, all other findings = 0; and the reading 01000001 means that b = 1, h = 1 and all other findings = 0.

3. Recall from Steps 15-16 of the Preparation that five inputs to the 8-NAND gate on the counting frame were left vacant. Connect these inputs to the five vacant input sockets for the five diseases on the diagnosis INVERT card. The order is unimportant.

4. Check the programming of the student BIP: T to X, S to +, and W to -. Plug in the BIP.

5. The counter will input the full range of findings into the computer. Whenever one or more diodes light on the diagnosis INVERT card, the counter will stop. The set of findings producing the diagnosis may be read directly from the eight FLIP-FLOP diodes. For example, if the eight diodes register in sequence on-off-off-on-on-off-off-off, this represents 10011000. If the sequence of findings on the TRUTH TABLE card is abcdefgh, the FLIP-FLOP display 10011000 corresponds to $a \wedge \bar{b} \wedge \bar{c} \wedge d \wedge e \wedge \bar{f} \wedge \bar{g} \wedge \bar{h}$.

6. The stopping of the counter whenever a diagnosis appears permits one to make a written record of all those findings which produce diagnoses, if so desired. To restart the counter, merely switch the pulser to the opposite position and then back to the original position. Note that it is profitable to speed up the frequency of the counting so that long sequences giving no diagnoses will occupy negligible time.

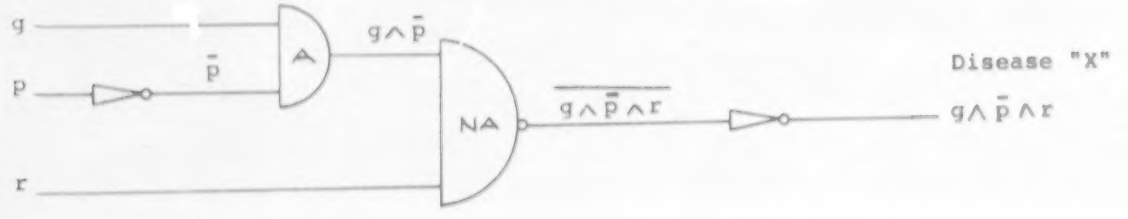
KEY--REVIEW SET 13:

1. 4 2. 4 3. 2 4. 1 5. 2-OR, 2-NAND, 2-NOR, 2-AND 6. 1

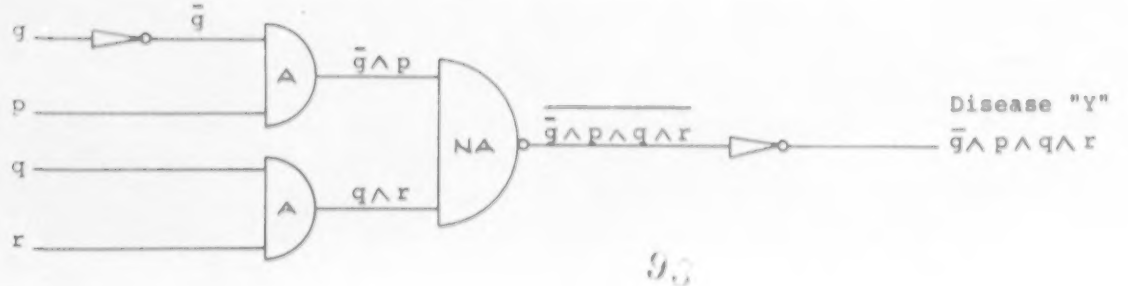
7. a. $q \wedge \bar{p} \wedge r$: Disease "X"

$\bar{q} \wedge p \wedge q \wedge r$: Disease "Y"

b.



c.



LESSON 14: SOURCES OF DRUGS

RATIONALE:

This lesson introduces a sequence of lessons on drugs. Most of the drugs that will be discussed in this sequence act via the nervous system, and their actions can be related to what students have learned earlier in this unit. ST-14 focuses on the present-day use of medical drugs derived from plant and animal sources. It also points out that cultures with much simpler technologies than our own have drugs and use them for medical purposes. This approach is intended to emphasize (1) the fact that many drugs used in modern medicine are derived from plants or animals and were discovered not by modern medical scientists but by "primitive" or "folk" healers, and (2) the fact that pharmacology, whether "primitive" or modern, progresses mainly by trial and error. In LA-14, the students make four different kinds of pharmaceutical preparations based on plants or plant-derived substances. One of these (camphor) acts directly on the nervous system, stimulating some nerve endings and deadening others. Another (cáscara sagrada) is thought to act through the nervous system to increase peristalsis in the bowel, thus promoting defecation.

OBJECTIVES:

The student will:

- state why it is useful to study the medical practices of other cultures.
- name three plant-derived drugs now in use and their functions.
- name three animal-derived drugs now in use and their functions.
- compound simple pharmaceutical preparations, following written directions.

SEQUENCE: ST-14; LA-14

SUGGESTIONS:

1. In Biomedical Social Science Unit II, students have inquired into the health problems and practices of people living in a variety of cultures, most of them technologically "primitive" in comparison to our own culture. The treatment of health in Unit II emphasized interaction between people and their environments. Students may recall some examples illustrative of the awareness such "primitive" people have of the plants and animals in their environments. They may also recall some examples of the use of plant- and animal-derived substances as drugs (medical or otherwise) in the cultures they have studied. You may wish to consult with the Social Science instructor to determine whether any topics that arose in Unit II will be useful as "openers" for the present discussion.

2. The field of pharmacy is heavily dependent on organic chemistry, so it should be possible to review and build on the earlier treatment of organic chemistry of Unit II. Formulas may be considered from the standpoint of functional groups. Students may be interested in making molecular models of simple drugs.

3. If you wish more background on the drug lessons, the following references may be of use:

L.S. Goodman and A. Gilman, The Pharmacological Basis of Therapeutics, Fourth Edition, Macmillan, N.Y., 1970.

E.M. Brecher, Licit and Illicit Drugs, Little, Brown and Co., Boston, 1972.

A. Goldstein, L. Aronow and S.M. Kalman, Principles of Drug Action: The Basis of Pharmacology, Harper and Row, N.Y., 1968.

F.H. Meyers, E. Jawetz and A. Goldfien, Review of Medical Pharmacology, Second Edition, Lange Medical Publications, Los Altos, CA, 1970.

4. A placebo activity is included in the Instructor's Manual, Lesson 18.

For reasons explained in Lesson 18, the activity should be conducted out of sequence at approximately the time of Lesson 14 or 15.

INFORMATION ON LABORATORY ACTIVITY 14:

TEACHING NOTES:

1. In this activity the students prepare some medications from plant products. Students learn something about the work of a pharmaceutical chemist and about the chemistry and pharmacology of certain drugs.

2. Anticipated time: two periods plus approximately 20 minutes on a second day for completion of Part III. The parts of the activity should be performed in the order provided since this increases the likelihood of successful completion within the indicated anticipated time.

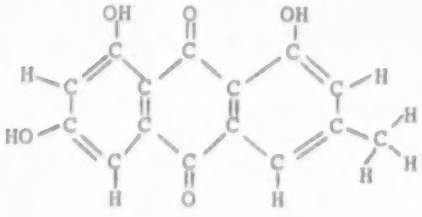
3. Wild-cherry powder, witch-hazel leaf, camphor and cáscara sagrada (cáscara-buckthorn bark) may be purchased at herbalists' shops and some natural-food stores.

4. The students should be cautioned not to ingest any of the preparations made in this activity. The drugs intended for consumption do not contain significant amounts of toxic ingredients. However, laboratory glassware may be contaminated, and the students may make mistakes.

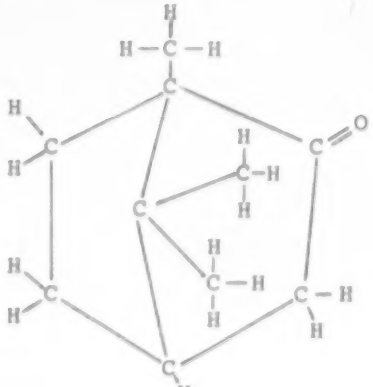
5. It is not intended that the students memorize the meanings of the vocabulary words. The definitions are provided only for the students' interest and reference.

6. In the activity it is assumed that graduated beakers are available. If such beakers are not used, a 100-ml graduated cylinder is needed for each part.

7. Students may be interested in the structures of some of the active components of the drugs being prepared. Two are shown below.



Emodin



Camphor

8. "Purified" sand is specified because this is what would be used by a pharmaceutical chemist. Since the drugs prepared in the activity are not intended for consumption, sand from a garden, hardware or pet store is suitable. (If desired, the sand may be purified by washing it with dilute (10%) HCl, followed by thorough washing with water. Purified sand may be purchased from laboratory-chemical suppliers.)

9. When packing the acrylic column, students should use just enough cotton to prevent the sand from being washed into the percolate. Excess cotton absorbs and holds too much of the percolate.

10. In Part I, sucrose is added to the wild-cherry preparation as in standard procedures. However, for the purposes of this activity, the addition of sucrose may be bypassed.

11. While the instructions for Parts I and III specify an acrylic column of the type used in Unit II, LA-36, a 50-ml buret may be substituted. If a buret is

used, each set-up requires a funnel and a long glass rod or tube (that will reach the bottom of the buret) to pack the column. Burets may be cleaned by connecting the bottom of the column to a faucet with a rubber hose. Water pressure may be adjusted to force all material (cotton, sand, filter paper and plant) from the column.

12. If tea strainers are not available for Part II, cheesecloth may be used to strain the cáscara-sagrada infusion.

MATERIALS: (for 15 set-ups)

PART I:

Materials for 15 percolator set-ups:

- 15 acrylic tubes, 7/8" I.D., 30-cm long (see Teaching Note #11)
- 100 ml sand, purified
- cotton, non-absorbent
- 15 rubber stoppers, one-hole, #4
- 15 rubber stoppers, solid, #4
- 15 filter papers, Whatman #1, 7-cm or greater
- 15 pinch clamps (or screw clamps)
- 100 cm rubber tubing, 3/16" I.D.
- 100 cm glass tubing, 6 mm O.D.
- 15 ring stands
- 15 ring-stand clamps
- 60 g wild-cherry powder
- 60 ml glycerin
- 250 g sucrose (table sugar)
- 30 beakers, 50-ml
- 15 pipets, 10-ml
- 15 glass stirring rods
- 15 balances

PART II:

- 25 g cascara sagrada (cáscara-buckhorn bark--a coarse powder)
- several tea strainers
- 30 beakers, 150-ml
- 15 covers for beakers (watch glasses or Petri-dish lids)
- 15 gas burners
- 15 ring stands
- 15 ring-stand rings
- 15 wire gauzes
- 15 glass stirring rods
- 15 tongs (or asbestos gloves or pot holders)
- 15 balances

PART III:

- 15 percolator set-ups (see Materials List, Part I)
- 200 g witch-hazel leaf (a coarse powder)
- 25 ml glycerin
- 400 ml ethyl alcohol, denatured, 95%
- 30 beakers, 50-ml
- 30 pipets, 10-ml
- 15 glass stirring rods
- 15 balances

PART IV:

- 25 g camphor
- 200 ml ethyl alcohol, denatured, 95%
- 15 beakers, 50-ml
- 15 pipets, 10-ml
- 15 glass stirring rods
- 15 balances

ANTICIPATED RESULTS:

PART I:

The wild-cherry syrup will have a familiar, strong aroma. It will be orange to red in color.

PART II:

Since the infusion is not to be ingested in the activity, its cathartic properties cannot be tested. Expect a strong aroma.

PART III:

The product will smell and feel like commercially prepared witch hazel.

PART IV:

Camphor has a familiar fragrance. When applied to the skin it may cause reddening as well as a numbing and cooling sensation.

ANSWERS TO DISCUSSION QUESTIONS:

1. Answers will vary. Students may have used cough medicines made with cherry syrup.

2. Answers will vary. Students may have used witch hazel topically for a variety of purposes.

3. Spirits contain alcohol, which evaporates quickly.

4. Coffee and tea are usually prepared as infusions, coffee by percolation (a filter coffee maker is a percolator in pharmaceutical jargon) and tea by maceration.

5. The active ingredients in cáscara sagrada are not affected by temperatures up to 100 °C. The hydrolysis of mandelonitrile glucoside in wild-cherry bark, however, cannot occur at high temperatures. The enzymes responsible for the hydrolysis are denatured and inactivated by heat.

LESSON 15: INTRODUCTION TO PHARMACOLOGY

RATIONALE:

Many drugs are important to modern medicine as tools for the prevention, diagnosis, treatment or cure of disease. Many others are important as contributing causes of disease. This lesson introduces the subject of pharmacology, and the lessons to follow provide more detail on drugs important to health-care providers.

OBJECTIVES:

The student will:

- define the terms drug (as used in this course) and pharmacology.
- list at least three kinds of information about a drug that may be found in a pharmacology book.
- describe the action of penicillin on bacteria, its effects on the body and its possible side effects.

SEQUENCE: LA-14 (complete); ST-15

SUGGESTIONS:

1. The following questions may be used to start a discussion.

a. What criteria must a drug meet in order to be classified as a medical drug? Is a substance that meets these criteria always a medical drug, even when it is not being used for medical purposes? (For the purpose of this sequence, it is; such a substance is always a medical drug, no matter how it is used in a particular situation.)

b. Suppose a biochemist has discovered that substance X inhibits, or blocks, a certain chemical reaction in test tubes. Furthermore, suppose a physiologist has discovered that this same substance X, when injected into experimental animals, alters a particular nerve-impulse transmission. What do the two studies suggest about the physiology of the experimental animals? (They suggest that the particular chemical reaction inhibited by substance X may be involved in the particular nerve-impulse transmission tested in the experimental animals.) You may want to pursue such questions as how this discovery might turn out to be useful in clinical medicine and what sort of research would have to be done first. The point of the question is that research on pharmacological effects of substances can produce new knowledge about how our bodies work, as well as new drug therapies.

2. Students could investigate some practical aspects of drugs. Some areas of study are suggested below. The exercise would supplement the discussion of drugs in the Student Text and provide insight into pharmacy as a career. A short description of pharmacy and related careers is given at the end of this lesson.

a. Categories of Drugs

Students could be assigned to visit drugstores and identify the brands of over-the-counter (nonprescription) drugs in each of the following categories that are available in the store. The purpose of such a study is to relate the sometimes abstract treatment of drugs in this sequence of lessons to familiar medications.

(1) pain relievers such as aspirin, Bufferin, Excedrin, APC compound, Midol and Aspergum

(2) decongestants such as Dristan, Coricidin, Contac and nosedrops

(3) sleeping aids such as Sominex

(4) anti-sleep medications such as No-Doz

(5) cough medications such as Nyquil

(6) antimicrobial compounds such as alcohol, hydrogen peroxide, iodine, mercurochrome and soap

(7) sedatives such as Compoz

(8) complexion aids such as special soaps and Clearasil

(9) other skin medications such as those used for skin rashes, dandruff and athlete's foot

(10) diuretics (promote water loss)

(11) eye drops

(12) laxatives

(13) antidiarrhetics such as Kaopectate

(14) antacids such as Di-Gel and Tums

(15) hemorrhoid medications such as Preparation H

(16) medications for corns and bunions

(17) salves for muscle aches and joint pains (e.g., pain of arthritis)

(18) vitamins and minerals

To make this activity easier for students you might wish to assign different drug categories to different students.

b. Information on Labels

Another possible project involves analysis of drug labels. Students assigned this activity should review the earlier lesson on food labels (Unit 2, Lesson 39). In a study of drug labels, students could gather the following kinds of information.

(1) name or statement of identity of the product

(2) net quantity of contents

(3) active ingredients

(4) directions for use, including symptom to be treated, dosage, how frequently the drug should be taken, the maximum amount that should be taken in a day and the maximum number of days it should be taken

(5) warnings that the drug should not be used by people with certain health problems, if such is the case

(6) description of possible side effects and related warnings (e.g., not to drive under the influence of a drug that may make you drowsy)

(7) warnings that one should see a doctor if symptoms persist.

To help students in completing this project, you may wish to assign certain categories of drugs (from activity a above) to particular students.

c. Drug Purchases

If you have warned the pharmacist in advance (see "NOTES" below), students might ask the pharmacist for information about the sales of drugs in the various categories described in Activity a above. Which categories of drugs are bought by the largest numbers of people? Which bring in the largest amounts of money? Are any categories of drugs sold mainly to particular types of people (e.g., young or old, male or female, rich or poor)?

NOTES ON THE ABOVE ACTIVITIES:

1. To make these activities easier both for the students and for the pharmacists, you should select drugstores in your community and give the pharmacists advance notice about how many students will be coming, when they will be coming, what they will be looking for and what sort of questions they will be asking.

2. It would also be helpful to prepare a letter to pharmacists explaining what is happening and why, and to give each student a copy of the letter. Students can present the letter to pharmacists or sales people as a means of explaining their presence when they enter a store to complete these activities. A sample letter follows these notes.

3. It will be helpful if you can split up the class and send different students to different stores, so that the whole class does not descend upon a single pharmacist at one time. (If your community is small and has few pharmacists, you might consider inviting one in, instead of sending the class out.)

4. If the opportunity presents itself (and if you have given the pharmacists advance notice), students might talk to pharmacists about their work. What do they do? What is their role in the pharmacy? What sort of training have they had? What sort of information do they give people about drugs? Do they give customers advice? If so, what kinds of advice?

SAMPLE LETTER TO PHARMACISTS:

Dear Sir:

The Biomedical class of _____ High School is making a survey of non-prescription drugs that are sold in pharmacies. Students have been asked to gather the following kinds of information.

[Select from the following possibilities, according to the assignment or assignments you plan to give.]

1. Brands of drugs available in various categories, such as pain relievers, decongestants, sleeping aids and antimicrobial agents.

2. Information provided on the labels of nonprescription drugs, such as identity of product, net contents, active ingredients and directions for use.

3. Categories of drugs that are bought by the largest numbers of people, bring in the largest amounts of money or are bought by identifiable types of people (young or old, male or female, etc.).

[Add the next paragraph if you have assigned students to interview pharmacists about their work.]

In addition, students have been asked to talk to pharmacists about the kinds of work they do and the kinds of training they have had.

I would greatly appreciate your cooperation in helping the students complete this assignment.

If you have any questions or suggestions, please feel free to contact me at _____.

INFORMATION ON DRUG-RELATED HEALTH CAREERS:

Pharmacy:

The pharmacist (druggist) is a professional who prepares and dispenses drugs used in health care. These professionals have a minimum of five years of college. Pharmacy represents one of the more important health professions in terms of employment possibilities. Over the last twenty years, the number of practicing pharmacists in the United States has increased from just over 100,000 to approximately 130,000. The vast majority of pharmacists work in community pharmacies (drug stores); almost half of these people own or are partners in their stores. About 10% of pharmacists work in hospitals, and this is an area of rapid expansion. Hospital pharmacists are predominantly concerned with prescription drugs; they also make special preparations such as sterile solutions for use in the hospital. Another 10% of American pharmacists are employed in industry, government and educational institutions.

Pharmacology:

Pharmacy and pharmacology are terms often confused by the lay person. While pharmacists are mainly concerned with concocting and selling drugs, pharmacologists are more concerned with research on how drugs work and with creation of new drugs. There are about 8,000 pharmacologists in the United States. Pharmacologists generally have some graduate training; many have doctorates and work in highly specilized fields.

Clinical pharmacologists are concerned with how drugs work on human subjects and with the toxicity of drugs. Biochemical pharmacologists study the relationship of drugs to enzymes and metabolism. They are concerned with the mechanism of action of drugs at the molecular level. Chemotherapists typically study the effects of drugs on pathogens; they try to isolate or synthesize drugs that will specifically destroy disease-causing microbes. Many are also concerned with drugs effective against cancer. Toxicologists are concerned with the safety of drugs, side effects and effects of overdose. Many toxicologists are involved in ecological work such as

pollution control. Many pharmacologists specialize in drugs specific for particular body systems, such as neurological drugs, cardiovascular drugs and drugs that affect the endocrine system.

LESSON 16: (A) CATEGORIES OF DRUGS

(B) ANTIBIOTICS AND SOIL MICROORGANISMS

RATIONALE:

ST-16 extends the introduction of drugs presented in ST-15 and describes the major categories of medical drugs. In LA-16, students begin a series of laboratory investigations involving soil microorganisms and antibiotic activity. Antibiotics and other antimicrobial drugs constitute a significant proportion of therapeutic drugs.

OBJECTIVES:

The student will:

- list and give examples of at least five different categories of drugs.
- distinguish between habituation and addiction.
- isolate colonies of bacteria and molds from a soil sample.

SEQUENCE: ST-16; LA-16

SUGGESTIONS:

1. ST-16 is rather lengthy and detailed. You may wish to treat it as reference material rather than as a lesson to be mastered. For this reason, the objectives listed are minimal.

2. Many possible drug-related laboratory activities are inappropriate for use in high-school classes, for a variety of reasons. Some are too complex, some are too expensive, some are too dangerous and some are ethically problematic. To avoid these difficulties, we have chosen a series of activities on antibiotics and soil microorganisms. Antibiotics and related drugs are important in pharmacology and, aseptic techniques are of value to many health practitioners.

3. Lesson 16 suggested a student survey of nonprescription drugs available in pharmacies. If you have elected this option, you may find the following suggestions of use for a discussion of the results.

a. How would the students classify the drugs that they examined, using the pharmacological categories discussed in ST-16?

b. What information was given on the labels of the drugs? The Food and Drug Administration (FDA) requires:

(1) the name of identity of the product

(2) the net quantity of contents

(3) the active ingredients

(4) the name and place of business of the manufacturer, distributor or packer

(5) directions for use, including symptom to be treated, dosage, how frequently the drug should be taken, the maximum amount that should be taken in one day and the maximum number of days the drug should be taken

(6) warnings that the drug should not be used by people with certain health problems, if such is the case

(7) a description of possible side effects and related warnings (e.g., not to drive under the influence of a drug that may make you drowsy), and

(8) a warning that one should see a doctor if symptoms persist.

c. Which types of drugs were available under the largest numbers of brand names?

d. If the information was obtained, which types of drugs does the store sell the most of?

4. A listing of the most commonly prescribed drugs in the U.S. follows these suggestions. You may find it useful to make copies of the list for a discussion. You may wish to have the students compare the list of the most commonly prescribed drugs and the class' findings about the largest-selling nonprescription drugs. Are the most commonly used prescription and nonprescription drugs in the same pharmacological category?

5. If the students were able to talk to a pharmacist, what types of information did he or she provide?

a. Does the pharmacist give advice to customers? What kinds of advice?

b. What kind of training has the pharmacist had?

c. What are the position and the functions of the pharmacist in the pharmacy?

INFORMATION ON LABORATORY ACTIVITY 16:

TEACHING NOTES:

1. The purpose of this activity is to give the students the opportunity to (1) use culture techniques on microorganisms from the soil and (2) test these microorganisms for antibiotic activity against bacteria.

2. Anticipated time: Part I, one period, Part II, one period, Part III, part of a period.

3. Considerable preparation of sterile materials is required for this and the other microbiological activities in this sequence (LA-16, 18, 19, 20). See the table in "Preparation of Materials" (on page). It is suggested that you use student help as much as possible in the preparations; this would benefit the students as well as yourself.

4. Every activity includes the use of agar slants of the living bacteria Serratia marcescens and/or Staphylococcus aureus. For the latter, be sure to order the nonpathogenic, i.e., coagulase-negative, strain. LA-19 calls for living Penicillium. Be sure to order it on a plate and not on a slant so that there is enough for the class. These items are available from Carolina: agar slant of Serratia marcescens (Carolina #15-5450), agar slant of Staphylococcus aureus (Carolina #15-5555), plate culture of Penicillium notatum (Carolina #15-6157) Colonies of Serratia marcescens are typically bright red and Staphylococcus aureus colonies are generally yellow or yellow-white. The colors provide an easy way to check for contamination during the course of these investigations.

5. For information on sterile disposable Petri dishes, as well as other suggestions for and/or alternatives to agar plates, inoculating loops, and test-tube caps, see Unit II, Instructor's Manual, pp. 173-174. For information on incubators, see Unit II, Instructor's Manual, p. 58. Two or three incubators should suffice. Nichrome wire may be used for making inoculating loops, if necessary.

6. Forceps rather than an inoculating loop are used to transfer the fungus from one agar plate to another, for convenience in removing the fungus.

MOST COMMONLY PRESCRIBED DRUGS

UNITED STATES 1973

RANK	DRUG	PHARMACOLOGIAL CATEGORY
1	Valium	Sedative
2	Librium	Sedative
3	Darvon	Analgesic
4	*Tetracycline	Antibiotic
5	Premarin	Hormone (estrogen preparation)
6	Empirin with codeine	Analgesic
7	*Ampicillin	Antibiotic
8	Lasix	Diuretic
9	Ovral	Hormone (oral contraceptive)
10	V-Cillin K	Antibiotic
11	Indocin	Analgesic, antifever and anti-inflamatory agent
12	Donnatal	Antispasmodic, sedative
13	HydroDIURIL	Diuretic
14	Dimetapp	Decongestant
15	Actifed	Antihistamine-decongestant
16	Lanoxin	Similar to digitalis
17	Benadryl	Antihistamine
18	*Phenobarbital	Barbiturate
19	Erythrocin	Antibiotic
20	Ilosone	Antibiotic
21	Aldomet	Antihypertensive
22	Achromycin V	Antibiotic
23	Diuril	Diuretic
24	Sumycin	Antibiotic
25	Lomotil	Antidiarrhetic
26	Ovulen 21	Hormone (oral contraceptive)
27	Dyazide	Antihypertensive, diuretic
28	Butazolidin alka	Anti-inflammatory agent
29	*Thyroid	Hormone
30	Fiorinal	Analgesic-sedative
31	Librax	Sedative
32	Ornade	Antihistamine-decongestant
33	Thorazine	Tranquilizer
34	Elavil	Antidepressive sedative
35	Dilantin	Anticonvulsant
36	Mellaril	Tranquilizer
37	Orinase	Antidiabetic agent
38	Phenaphen with Codeine	Analgesic sedative
39	Triavil	Tranquilizer, antidepressive
40	Prednisone	Anti-inflammatory agent

* All drug names listed are brand names unless marked with an asterisk.

7. Nutrient-agar powder and nutrient-broth powder will also be used in later activities in the curriculum. Four ounces of each, the quantities in which they are commonly sold, will provide enough for several years, so they are a good investment.

8. The number of agar plates needed may be halved by using citrus fruits instead of plates as a culture medium for growing fungi. This also eliminates the need to prepare soil samples. Place the rinds from two or three fruits in a plastic bag and incubate them at room temperature for 2 to 3 days. The fungi that grow may have antibiotic activity. They can be used instead of the ones in the "soil-sample" plates in Part II.

9. It may be helpful to students if you demonstrate how to pour agar into a sterile Petri dish (Part I), and how to use a loop or forceps to transfer microorganisms from one plate to another (Part II).

10. It is not likely that many antibiotic-producing molds will be found. Relatively few microorganisms produce antibiotics. You may wish to remind the student that the pharmaceutical industry tests many soil and other samples before one is found. The value of this activity, even if students do not find an antibiotic producer, derives both from practice of microbiological techniques and from the insight students will gain into how the search for these new drugs is made. LA-19 involves a known antibiotic-producing mold and therefore provides more likelihood of success in a similar activity.

11. The more different species of microorganisms tested, the more likely an antibiotic producer will be found. Encourage the students to compare the appearance of colonies on different plates in Part II and to select as many different types of colonies as possible for testing antibiotic activity.

12. The following options are available.

a. Have students test the antibiotic properties of garlic. To do this a clove of garlic is halved along its length and then a slice about 2 mm thick is cut. Remove the skin. The garlic slice is then placed on a freshly seeded agar plate of bacteria. After incubation for 1 to 2 days, a ring of inhibition will be seen.

b. If a properly prepared copper coin is placed in a Petri dish containing melted agar, the small amount of metal that dissolves will have a toxic effect on bacteria. This can be demonstrated by students as follows.

The coin is prepared by immersing it in a tenfold dilution of concentrated nitric acid for 10 to 20 seconds and then washing it thoroughly in water to remove the nitric acid.

Melt the agar in a sterile nutrient-agar tube, and then cool it down in warm water from the tap at 45 to 50 °C. Seed this melted agar with one loopful of a bacterial nutrient-broth culture. (Loop-transfer technique is given in LA-18, Part I, Steps 5 and 6.) Rotate the tube to obtain a uniform distribution of organisms. Pour the agar in one tube onto the prepared coin in the Petri dish.

MATERIALS: (for 15 set-ups)

PART I:

15 test tubes, 16 x 125 mm

materials for sterile nutrient-agar tubes (see Preparation of Materials, pp. 92 and 94--includes 9.3 g nutrient-agar powder and 30 test tubes with caps)

15 test-tube holders

30 Petri dishes, sterile

5 to 10 beakers, 600-ml, for hot water baths

15 stoppers, rubber, #6

germicide

paper towels

15 Erlenmeyer flasks, 250-ml

15 beakers, 250-ml

15 balances

5 to 10 thermometers

15 test-tube racks

15 1-ml pipets

15 10-ml pipets

15 glass-marking pencils

50 g soil

PART II: (for 15 set-ups)

30 agar plates from Part I

materials for broth-culture tubes of bacteria: (see Preparation of Materials, page . --includes 0.6 g nutrient-broth powder, 10 test tubes with caps, and culture of either S. marcescens or S. aureus)

15 inoculating loops

germicide

15 packets of sterile cotton balls, wrapped in aluminum foil

100 ml ethyl alcohol (70 to 95%), denatured, with cups or beakers for distribution

15 pieces of aluminum foil (approximately 10 cm x 10 cm) for disposing used cotton balls

15 glass-marking pencils

15 forceps

15 gas burners

PART III: (for 15 set-ups)

15 agar plates from Part II

15 mm rulers

PREPARATION OF MATERIALS:

1. Every activity in this sequence requires some prior autoclaving to prepare sterile materials. Students may perform the steps shown with an asterisk below. The table (on the following page) shows the materials requiring sterilization by prior autoclaving. With the table you can gauge the preparation time for each activity and possibly plan for preparing materials for more than one activity at one time.

2. Prepare materials long enough before the activity for them to have time to cool. Note that preparation of the culture tubes of bacterial suspension must be begun at least 2 days before the activity so that the bacteria have time to grow.

3. Autoclaving is the most time-consuming aspect of the preparation. Some schools have electric pressure cookers for autoclaves, which may take as long as 45 minutes to warm up. It may be wise to start the autoclave early, while preparing the items for autoclaving; this insures that the autoclave is warmed up when the items are ready for autoclaving. Media can be refrigerated before autoclaving if autoclaving cannot be done at once.

Sterile Cotton Balls:

*1. Break off pieces of absorbent cotton about one cm in diameter and wrap five each in a piece of aluminum foil. Fold the foil so that it can be easily unfolded. (Students put the packets in a designated place for autoclaving.)

2. Autoclave.**

Sterile Nutrient-Agar Tubes:

The materials for 15 set-ups are:

flask, 500-ml

hot water bath (or direct heating set-up)

* Asterisks signify preparations that students can perform.
**In each case, "autoclave" will mean 15 to 20 minutes at 15 pounds per square inch pressure.

LABORATORY ACTIVITY	NO. STERILE NUTRIENT-BROTH TUBES PER SET-UP	NO. STERILE NUTRIENT-AGAR TUBES AND STERILE PETRI DISHES PER SET-UP*	PACKETS OF STERILE COTTON SWABS PER SET-UP	PACKETS OF STERILE PIPETS PER SET-UP	TOTAL NO. TUBES OF BACTERIAL BROTH CULTURES	OTHER STERILE MATERIALS	ESTIMATED PREPARATION TIME, EXCLUDING AUTOCLAVING
16	———	2	1	———	5 to 10 (needed on second day)	———	1 to 1 1/2 hours
18	4	———	———	1	5 to 10	1 empty sterile capped test tube per set-up	1 to 1 1/2 hours
19	———	1	1	———	2 to 5 each of two different bacteria	———	1/2 to 1 hour
20	———	2	1	———	5 each of two different bacteria	1 packet sterile filter-paper disks per 2 set-ups	1 hour

* Each nutrient-agar tube calls for a sterile Petri dish.

30 test tubes, 16 x 125 mm
30 test tube caps, 18-mm
9.30 g nutrient-agar powder
stirring rod
balance
autoclave

1. Calculate how many ml of agar are needed. Assume 20 ml per set-up (10 ml per Petri dish).

2. 31 g of powdered nutrient agar make 1,000 ml of agar (enough medium for 100 plates). On this basis, calculate how many grams of powdered agar you need and weigh out this amount. (For 15 set-ups you would need 300 ml of agar, 9.30 g powder.)

3. Measure out a volume of tap water equal to the amount of agar needed, put it in a 500-ml flask and then add the measured powder to the water.

4. Dissolve the agar with heat. Use a boiling water bath or heat the agar directly with continuous stirring. It is important to stir if direct heat is used, otherwise the agar may burn on the bottom. Don't stop stirring until the agar is dissolved, for it may burn. Agar also has a tendency to foam over when it boils.

5. When the agar has completely dissolved, dispense about 10 ml of the agar into each test tube, two test tubes per set-up. Suggestion: Note the fluid level of 10 ml of water before pouring the agar. Then cap each tube. (If students do this, each team fills its two tubes. In this case the flask of agar must be kept warm for a longer period to prevent the agar from hardening. This may be done by placing it in a vessel of warm water from the tap at 45 to 50 °C. Students then cap the tubes, initial them, and put them in a designated place for autoclaving.)

If autoclaving is not done right away, the agar may be refrigerated for up to two weeks and remelted in a hot water bath when needed.

6. Autoclave the capped tubes. Don't depressurize the autoclave too rapidly afterward or the tubes will boil over.

7. Allow the tubes to cool, and set them aside for the activity.

Broth-Culture Tubes of Bacteria:

Tubes of nutrient broth are first prepared, sterilized and then inoculated with bacteria. Inoculation must be done at least one day before the activity to give the bacteria time to grow. Once broth cultures have grown 1 or 2 days, they may be kept viable for a week by storing under refrigeration (not freezing).

The broth-culture tubes made for one activity may be reused for other activities in the sequence, but additional tubes may be needed eventually as these are used up. You may therefore wish to prepare extra tubes of broth now and save them for use later. 5 to 10 tubes are sufficient for this activity. The materials needed for 10 tubes are:

prepared agar-slant culture of bacteria (Serratia marcescens or Staphylococcus aureus)
10 test tubes, 16 x 125 mm
10 test-tube caps, 18-mm
0.60 g nutrient-broth powder
germicide
balance
flask, 250-ml
autoclave
inoculating loop
gas burner

1. To make 10 tubes, dissolve .60 ± .03 g of nutrient-broth powder in 75 ± 5 ml of tap water. Distribute the nutrient broth into 10 test tubes, 16 x 125 mm. Pour approximately the same amount into each test tube. Then cap each test tube.

2. Autoclave. Don't depressurize the autoclave too rapidly afterward or the tubes will boil over.

3. When the tubes are cool, inoculate each of them with Serratia marcescens or Staphylococcus aureus from the agar slant. If you are not versed in aseptic

microbiological techniques, or would like a review, see LA-19, Part I, Steps 5 through 6.

4. Incubate the test tubes at 35 ± 3 °C. Mix once a day by jiggling.

ANTICIPATED RESULTS:

Many molds were obtained from two soil samples. However, no zones of inhibition were obtained on two agar plates tested in our laboratory.

ANSWERS TO PROCEDURE QUESTIONS:

PART II:

1. Our plates had a total of about 500 colonies.

2. Our plates had about 150 bacterial and 20 fungal colonies on the surface.

3. Bacteria were in far greater number than fungi in our plates--a ratio of 8 to 1.

4. There were about 500 colonies on each of our plates. This gives as estimate of about

$$\frac{500 \text{ organisms}}{\text{g diluted sample}} \times \frac{1{,}000 \text{ g diluted sample}}{\text{g soil}}$$

or 500,000 microorganisms per g of soil.

5. The lid is unsuitable because its position changes every time it is lifted and replaced.

ANSWERS TO DISCUSSION QUESTIONS:

PART I:

1. Examples of steps in which contamination may have occurred include lifting the lid of the Petri dish, collecting the soil sample, diluting the soil, and pipeting the soil. To help prevent contamination, one could use a sterile soil-collection container and collecting tool, sterile water and vessels for dilution, and a sterile pipet to transfer the diluted soil to the agar. Also good sterile techniques will help to minimize contamination.

2. Agar is a carbohydrate (polysaccharide) which in aqueous solution solidifies below 40 C. Agar is obtained from certain seaweeds. Nutrient agar is agar with NaCl, peptones (partially hydrolyzed proteins) and beef extract added to nourish microorganisms.

PART II:

1. Some microbes may have produced antibiotics, inhibiting the growth of others. More important, some organisms do not grow well in nutrient agar and would not be found. Other kinds of agar preparations have special nutrients that support the growth of soil microorganisms better.

2. To produce more colonies, don't dilute the soil sample as much. To produce fewer colonies, dilute the soil sample more.

3. $$\frac{150 \text{ colonies}}{\text{g of diluted sample}} \times \frac{5{,}000 \text{ g diluted sample}}{\text{g soil}} = \frac{750{,}000 \text{ colonies}}{\text{g soil}}$$

If each colony represents one organism, this means that there are 750,000 organisms/g soil.

4. Individual bacteria and fungi in the soil (or small groups of them) are microscopic in size. Visible colonies represent millions or billions of cells.

5. Fungi are common on virtually all surfaces. Given enough time and the proper conditions, such as moisture and nourishment, the fungi will grow and reproduce.

PART III:

1. There may or may not be contamination. It may occur at several points. See answer to Discussion Question 1, Part I.

2. An organism that produces an antibiotic inhibits other organisms that could otherwise compete more successfully with it for nutrients in the soil.

LESSON 17: (A) ANTIMICROBIAL DRUGS

(B) ANTIBIOTIC TESTING

RATIONALE:

ST-17 discusses the involved process by which a physician decides whether to prescribe a drug and which drug to use. The stress is on antibiotics because of the laboratory activities on antibiotics and soil microorganisms. The use of antibacterial agents to control bacteria in the environment is also discussed.

OBJECTIVES:

The student will:

- describe the steps by which a doctor decides whether drug therapy is indicated.
- list at least five antibacterial agents and state how each is effective in combating bacteria in the environment or in the body.
- give an example of chemotherapy.
- list four sites in or on a microbial cell that are vulnerable to antibacterial agents.

SEQUENCE: LA-16 (complete); ST-17

SUGGESTIONS:

1. The students may be interested in learning about references a physician uses for selecting a drug and how the physician learns about new drugs. A supplementary section (17-5) is provided, which can be reproduced and given to interested students. You may wish to invite a physician to speak about the use of references in the course of prescribing a drug, or you might be able to borrow a few standard reference books, such as a "Physicians' Desk Reference," used for selecting drugs for therapy. Students could leaf through these references if interested.

2. The structures of some antibacterial agents are shown in ST-17 to provide an opportunity to review organic chemistry. You might ask students whether they can identify the functional groups in the compounds shown. Students may also be interested in constructing molecular models of the antibacterial agents discussed.

3. You might ask students to check their medicine cabinets and kitchens at home for antibacterial agents. On the following day the class could tabulate their data and see what agents are most frequently used by their families.

SUPPLEMENTARY SECTION:

17-5 Sources of Information

Where do doctors get their information?

How did Dr. Holliday know what things to look for in Wyatt's case in order to establish a diagnosis? How did he know which drug to prescirbe for the condition and what contraindications to look for? Basically, doctors are just like the rest

of us. They learn from experience, and what they do not know they look up in reference books.

Several specialized reference books may be of help to the physician in his decision on what drug therapy, if any, to prescribe for a particular condition. One of these is a manual on clinical therapeutics. This book contains information on how to confirm a diagnosis of a specific condition. This is followed by instructions for treating the condition.

Another reference book used by doctors is similar in many ways to a pharmacology book. It is the Physicians' Desk Reference, or PDR. The PDR supplies specific information on the effects, contraindications, dosage levels, methods of administration, etc., for each drug. The information contained in the PDR is supplied by the manufacturers of the drugs listed.

The PDR also has a section containing full-size color pictures of over 1,000 capsules and tablets. This section was especially created to aid the medical professional in identifying drugs. Many times it is important to determine what prescription drug the patient has been using, but the patient cannot recall the name of the medication and does not have the prescription. If the patient can bring in a sample, the doctor or nurse may be able to identify it using the section of the PDR provided for this purpose.

As the number of available drugs increases, computerized access to information about drugs becomes more desirable as a supplement to reference books. One system that gives doctors such access is called MEDLARS (Medical Literature Analysis and Retrieval System). The doctor can telephone a programmer at a computer terminal and give him a few key words such as "penicillin" and "therapy," or "penicillin" and "adverse effects." The programmer converts these key words into computer language and types a few lines into a computer terminal. In less than a minute the computer responds with a long list of recent, relevant articles in medical journals.

LESSON 18: PLACEBOS

RATIONALE:

In pharmacology and medicine, it is often important to distinguish between a placebo effect and a direct physiological effect of a drug. ST-18 describes the placebo effect and the applications of placebos in clinical medicine and medical research. In Activity 18, described after the Suggestions in this lesson, the students study the placebo effect within their class.

OBJECTIVES:

The student will:

- explain what is meant by the term "placebo" and give an example of the placebo effect.
- describe two applications of placebos in medicine.
- give an example of each of the following: control group, experimental group, blind experiment, double-blind experiment.
- describe the effect(s) of a placebo taken in the classroom on himself or herself.

SEQUENCE: Activity 18; ST-18; LA-18

SUGGESTIONS:

1. It is essential that Activity 18 precede the students' reading of ST-18 because ST-18 describes the placebo effect. Student anticipation of a placebo effect is likely to invalidate the activity. One way to increase the chance that students will not have read ST-18 prior to Activity 18 is to schedule this activity a few

days in advance of Lesson 18. For example, the activity might be done immediately after Lesson 14.

2. After Activity 18 has been performed by different Biomedical classes, it is possible that some students may recognize that this is "the placebo activity." This discovery would invalidate the activity. If this happens, you could select subjects from outside the class and allow your students to participate in a repetition of the test.

3. In Section 18-3, there is reference to control and experimental groups. After checking to make sure that students understand the difference between control and experimental groups, you might ask them to give examples of activities they have performed in the Biomedical curriculum (in either Science or Social Science) that included both control and experimental groups. They might mention, for example, the experiment on Daphnia heart rate in Unit III.

4. The following discussion questions may be useful in presenting Lesson 18.

a. Would you expect a person who is easily hypnotized to be the sort of person who gets relief from placebos? Why or why not? (Hypnotism works by suggestion; the placebo effect may also depend on suggestion. If it does, then a person who is easily hypnotized should be able to get relief from placebos.)

b. Do you think the placebo effect works when a doctor prescribes a pharmacologically active drug, such as penicillin? Why or why not? (It probably does. A patient who is able to get relief from a placebo can probably get relief from the placebo effect, not matter what the doctor gives him. Such a patient would presumably get not only the desirable effects of the penicillin on his infection, but also whatever comfort and relief he derives from the fact that he is receiving some kind of treatment from a doctor.)

c. Do you think the placebo effect works in faith healing? (It might. If a patient believes that a faith healer is able to provide relief, then the faith healer might be able to provide relief.)

d. Why is it necessary to match an experimental group and a control group for age, sex and other variables that might affect the outcome of the experiment? Give examples of ways in which failure to match groups could result in incorrect conclusions from the experiment results. (Many examples are possible. One is the situation in which most of the subjects in an experimental group are old and most of those in the control group are young. If the new drug is less effective on old people than on young people--perhaps because of differences in metabolism, hormonal balances, etc.--then this experiment might cause one to conclude falsely that the new drug is ineffective.)

5. Students might wish to discuss the ethical problems associated with medical use of a placebo. Your Biomedical Social Science colleague mgiht be interested in this lesson and might have some good suggestions for a discussion on placebo-related ethical problems.

ACTIVITY 18: THE PLACEBO EFFECT:

This activity is presented here, rather than in the Laboratory Manual, because it includes information that the student is not supposed to know until after the activity.

This activity is intended to illustrate the effect of a placebo. Its success will depend to a large degree on how convincing you are in presenting the activity. The teaching notes include important suggestions that may help convince the students that they are receiving an effective drug.

MATERIALS: (for 30 students)

- 30 gelatin capsules
- 2 packages unsweetened drink mix, different colors (e.g., green and red)
- 30 g table sugar (sucrose)
- 2 pill bottles, 15-capsule capacity
- 30 paper cups (optional)

PROCEDURE:

1. Explain that two harmless drugs will be tested in an activity and that, for the investigation to be valid, any students who have taken a prescription drug within the last 24 hours will not be allowed to test these drugs. Such students will be part of a control group.

2. Divide the class into three groups of approximately equal size. Groups A and B will be given placebos A and B, respectively. Group C will be a control group who will not be given either placebo. Students who indicate that they have taken a prescription drug in the last 24 hours should be placed in the control group. To bring the control group to approximately the same size as the other groups, it may be necessary to add students who do not wish to test a drug and other students as well.

3. Show the students the two bottles of pills and explain that each bottle contains a different, nonprescription drug. State that one of the drugs is a mild hypnotic; it causes people to become relaxed and sleepy. The other drug is a diuretic. Explain that the students' task will be to try to figure out which kind of drug they took. Students must not talk to others in the class about their reactions to the drug until the discussion period.

4. Point out that each drug takes 20 to 40 minutes to produce its maximum effect.

5. During the waiting period, provide some other activity to keep the class occupied. (The activity should not be so stimulating that the students will be distracted from the placebo activity.) For example, during the 20- to 40-minute wait, the students could do some assigned reading or watch a film.

6. Allow the students to take the capsule appropriate for their group. They should record the code letter and the time they take the "drug." The students should be reassured that the effects of the pills will wear off within one hour and that their performance in other classes, driving or at work will not be affected.

7. Have the class proceed with the activity planned. Remind the students that they should feel free to go to the restroom if they need to.

8. After twenty or more minutes, discuss students' responses.

9. After tabulating the results for the three groups, reveal the contents of the capsules. Explain that the deception used is a requirement for the placebo effect. The students should next read ST-18, even if it will be out of sequence.

10. In Mathematics Unit II, Student Text, Section 32, students have studied the use of chi-square to analyze the results of experiments comparing new drugs to placebos. The following discussion topics might be used to reinforce students' understanding of chi-square analysis and to re-introduce the use of placebos in real drug experiments (described in ST-18).

a. Ask students to describe how chi-square analysis is used to determine whether a new drug is more effective than a placebo. (See Mathematics Unit II, Student Text, Section 32.)

b. Ask students to imagine that they had been told at the outset that drug A was a stimulant and drug B was a diuretic. Also ask them to assume that the third group, rather than taking no pill at all, had taken an over-the-counter caffeine pill (e.g., No Doz). If this procedure had been carried out, how would students use chi-square to determine whether caffeine is more effective than a placebo as a stimulant? as a diuretic? (Find out how many in the "drug A" group felt stimulated and how many in the "caffeine" group felt stimulated; compare the numbers and analyze as described in the Mathematics Text; the results should show whether caffeine is significantly more effective than a placebo as a stimulant. Similarly, compare the diuretic effects of caffeine and drug B; results should show whether caffeine is significantly more effective than a placebo as a diuretic.)

INFORMATION ON ACTIVITY 18:

TEACHING NOTES:

1. The purpose of this activity is to demonstrate the placebo effect.

2. Anticipated time: one period.

3. To make the activity convincing, the capsules, pill bottles and labels should look as professional as possbile. A pharmacist might have suggestions on packaging.

4. Students may detect the flavoring agents or sugar in the capsules. If comments are made, you could tell the students that capsules include a flavoring agent and sugar to make them more palatable.

5. You may wish to design and use a variation of this procedure. Many variations of the theme are possible. For example, you could tell the students at the outset that drug A is the one that makes people sleepy and drug B is the diuretic, and see how they respond.

6. It is possible that empty capsules may be difficult to obtain due to local restrictions. However, gelatin-filled capsules may be obtained in a grocery store. Such capsules may be emptied and refilled with the drink mix-sugar mixture.

7. In this activity, a mixture of unsweetened drink mix and sugar is used. The sweetened mixes are not suitable for this activity because they are too sweet--if tasted, the students may be suspicious about their nature.

8. To increase the credibility of the activity, you might tell the students that the dispensing of drugs in the classroom is prohibited by state law, but that a special exemption has been obtained in this particular case.

PREPARATION OF REAGENTS:

Drug (Placebo) A: To the contents of one package of drink mix, add 15 g of table sugar and mix well. Dispense the powder into 15 capsules. Put the capsules into the pill bottle and label.

Drug (Placebo) B: Prepare in the same way as drug A except use a different-colored drink mix.

ANTICIPATED RESULTS:

If the presentation is convincing, it is likely that at least some students will experience the placebo effect.

INFORMATION ON LABORATORY ACTIVITY 18:

TEACHING NOTES:

1. The purpose of this activity is to give students the opportunity to develop sterile techniques and apply them in testing the effects of antibacterial agents on bacterial growth.

2. Anticipated time: Part I- half period, Part II- half period, Part III- half period.

3. Sterile technique (Part I) is used in this and in future activities. It is therefore important that students learn it properly.

4. It is important to perform the colorimetry (Part III) about 24 hours after the tubes are inoculated. A longer interval would allow bacteria in all the tubes to reach the same maximum population, obliterating any differences among the tubes.

5. Only one control tube is specified for the activity. It would be mofe appropriate to have two controls, one for Tube 1 and one for Tube 2. The procedure calls for only one control because the difference in growth in a tube inoculated at

2 1/2 minutes and one inoculated at 10 minutes is not significant in the absence of an antibacterial agent. Also, fewer controls tends to minimize teacher preparation time.

6. The graph in LA-18 was obtained in our laboratory, using the bacterium Serratia marcescens. Although not precise, the graph provides an opportunity to quantitate the data.

7. The 600-ml beaker is provided for students to discard the 1-ml pipets that have been used to pipet bacteria.

8. Either Serratia marcescens or Staphylococcus aureus may be used in this activity. Students may be interested in comparing the effects of the antibacterial agents on both species to determine which species is more resistant to the agents.

9. The following options are available.

a. Each student may test two antibacterial substances rather than one, or make tests of a substance at two different concentrations. Note: this option would double the number of nutrient-broth tubes needed.

b. Crystal violet is a common antimicrobial agent used to treat thrush, a fungus disease of the mouth. Its use resulted in the violet tongues once commonly seen in children under treatment. Place 1 ml of a 1:10,000 dilution of crystal violet in an empty sterile Petri dish, spread it over the bottom by moving the dish, and then pour in the agar. Use a sterile cotton ball to seed the surface of the hardened agar with bacteria. Staphylococcus aureus is especially susceptible to this agent.

MATERIALS: (for 15 set-ups)

PART I:

- 15 pipets, 1-ml
- 30 test tubes, 16 x 125 mm
- 30 test-tube caps, 18-mm
- 15 beakers, 250-ml
- 15 inoculating loops
- 15 gas burners
- clock(s) with second hand
- 15 test-tube racks
- aluminum foil

PARTS II AND III:

- antibacterial agents (such as 70% alcohol, 0.5% phenol, 3% H_2O_2, household disinfectants, etc.)
- 30 test-tubes, 16 x 125 mm
- 30 test-tube caps, 18-mm
- materials for sterile nutrient-broth tubes (see Preparation of Materials, page includes 2.4 g. nutrient-broth powder and 60 test tubes with caps)
- materials for broth-culture tubes of bacteria (see Preparation of Materials for LA-16, page includes 0.6g nutrient-broth powder, 10 test tubes with caps, and culture of either Serratia marcescens or Staphylococcus aureus)
- 15 pipets, 10-ml
- 15 pipets, 1-ml
- 15 glass-marking pencils
- 15 test-tube racks
- 15 inoculating loops
- 15 gas burners
- germicide
- incubator
- aluminum foil
- 15 BIP colorimeters (Part III only)
- absorbent cotton

PREPARATION OF MATERIALS:

The table in Preparation of Materials for LA-16 shows the items requiring sterilization by autoclaving. Students can do much of the preparation themselves; such steps are indicated below by an asterisk. Preparation of Materials for LA-16 also contains important general information.

Broth-Culture Tubes of Bacteria:

The preparation of broth cultures is described in Preparation of Materials for LA-16. The broth cultures used in LA-16 may be reused for this activity if they have been stored under refrigeration for no longer than one week.

Packets of Sterile Pipets:

*1. For each 1-ml pipet, roll a small piece of cotton into a cylindrical shape about 1 cm long and narrow enough to fit into the "mouth" end of a 1-ml pipet. The cotton plugs are used as a safety precaution to prevent bacteria from entering the mouth. Put a cotton plug into each 1-ml pipet.

*2. Wrap the plugged pipet and an unplugged 10-ml pipet in aluminum foil, to keep dust out--one wrapped pair per set-up. Wrapping paper can be used instead, but it needs to be tied to keep it closed. (If convenient, preparing two wrapped pairs per set-up may be useful to provide margin for student error later.)

3. Autoclave. (Students should place wrapped tubes in a designated area for autoclaving.)

Sterile Nutrient-Broth Tubes:

The materials necessary for making sterile nutrient-broth tubes for 15 set-ups are:

flask, 500-ml
60 test tubes, 16 x 125 mm
60 test-tube caps, 18-mm
2.4 g nutrient-broth powder
stirring rod
balance
autoclave

1. Determine the total volume of nutrient broth needed for the activity: assume 20 ml per set-up (i.e., for four tubes).

2. 8 ± .2 g of nutrient-broth powder are needed to make 1,000 ml of nutrient broth. On this basis, calculate how many grams of nutrient-broth powder you need and weigh this amount. (For 15 set-ups you would need 300 ml of broth, 2.4 g powder.)

3. Dissolve the powder in the correct volume of warm tap water. (The flask should be covered and refrigerated if the next steps are not done immediately.)

*4. Place 5.0 ± 0.2 ml into each test tube, using a 10-ml pipet or a buret to dispense the broth. (Students may take turns using a single buret, each team filling its own tubes, four per set-up).

Cap each tube. (Students initial tubes and place them in a designated place for autoclaving. In this case the glass-marking pencil must be of a type whose writing can withstand autoclaving.) If the capped tubes are not autoclaved immediately, refrigerate them.

5. Autoclave. Don't depressurize the autoclave too quickly or the tubes will boil over.

Sterile Empty Capped Test Tubes:

*1. For each set-up, place an 18-mm cap on a 16 x 125 mm test tube.

2. Autoclave.

ANTICIPATED RESULTS:

The table on the following page shows the results obtained in our laboratory with Serratia marcescens.

Substance	Tubes inoculated after 2 1/2 minutes			Tubes inoculated after 10 minutes		
	% Transmittance	Absorbance	Number of bacteria/ml	% Transmittance	Absorbance	Number of bacteria/ml
70% ethyl alcohol	89	.050	2,200,000	89	.050	2,200,000
0.5% phenol	84	.075	3,300,000	88.5	.055	2,400,000
3% hydrogen peroxide	94	.025	1,100,000	96	.015	700,000
Lysol (pine scent) (2 teaspoons in 1 quart of water)	91	.040	1,800,000	94	.025	1,100,000
Mr. Clean (1/4 cup in 1 gallon of water)	83	.080	3,500,000	87	.060	2,600,000

The control had a % transmittance of 77, an absorbance of .115, and a population of 5,100,000/ml.

ANSWERS TO DISCUSSION QUESTIONS:

1. The results obtained in our laboratory show a decrease in population for phenol, hydrogen peroxide, Lysol and Mr. Clean. This indicates that these agents continued to kill bacteria between 2.5 and 10 minutes after addition to the bacterial suspension. A control run in our laboratory showed no significant change with time.

2. In our laboratory, yes. The larger population in the control tube indicates that the antibacterial substances killed some bacteria. The control was needed to show that the bacteria did not die because of exposure to broth for a period of up to 10 minutes.

3. In our laboratory, yes. Different agents killed different numbers of bacteria; some were more effective than others.

4. Bacteria scatter light and thus block some of the light passing through the broth. When less light reaches the photocell of the colorimetry well, the absorbance of a solution increases.

5 Household bacteria may be of types that are more sensitive to the disinfectant. Also, household surfaces are not likely to have the concentration of bacteria used in this activity.

A test could be done to measure the bacterial population on the surface before and after application of the disinfectant. This could be done by wiping the surface with a sterile cotton ball before and after the agent is applied and then placing each ball in nutrient broth.

6. Our results show 3% H_2O_2 to be the best disinfectant, but far from perfect. It could be applied with a paper towel.

LESSON 19: ALCOHOL

RATIONALE:

The use of drugs such as alcohol for nonmedical purposes is important to medicine because such drug use can cause health problems. Excessive use of alcohol, in particular, as a nonmedical drug is a significant health problem because too much alcohol can produce habituation, tolerance, addiction, withdrawal symptoms, chronic gastritis, malnutrition, nervous-system damage and liver disease. Widespread alcohol use can have adverse affects on society by increasing the incidence of mental disorders, fatal car accidents, homicides and suicides. This lesson focuses on alcohol. Lesson 20 will focus on opiates, cocaine and marijuana and will compare and contrast the pharmacological properties and consequences of use of these drugs and of alcohol.

OBJECTIVES:

The student will:

- state why nonmedical drugs are of importance to health-care providers.
- state at least three acute (immediate, short-term) effects of alcohol on the body.
- list at least three long-term effects of alcohol on the body of a chronic heavy user.
- describe at least three of the five stages of the alcohol withdrawal syndrome.
- test a species of Penicillium mold for antibiotic activity.

SEQUENCE: LA-19; ST-19

SUGGESTIONS:

1. Lessons 19 and 20 provide background on several important nonmedical drugs, namely, alcohol, opiates (including heroin and morphine), cocaine and marijuana. The emphasis in the Science Student Text is on the pharmacological effects of these drugs and the consequences of their nonmedical use; the Text deliberately avoids value judgments, since much of Social Science Unit IV is concerned with ethical questions and social norms regarding both medical and nonmedical drug use.

2. A speaker from Alcoholics Anonymous or another rehabilitation organization for alcoholics may be of interest. Look in the Yellow Pages of the telephone book under "Alcoholism Treatment and Information Centers" for possible sources of speakers.

3. Section 19-5 is closely related to Lessons 31 through 33 in Unit I, Biomedical Mathematics. It would be helpful to review these earlier mathematics lessons or discuss them with the Mathematics instructor prior to teaching Lesson 19. In addition, you may wish to point out to your class that the data in the Mathematics Text on rate of removal of alcohol from the blood is valid for most cases, but not valid for habitual drinkers because of tolerance.

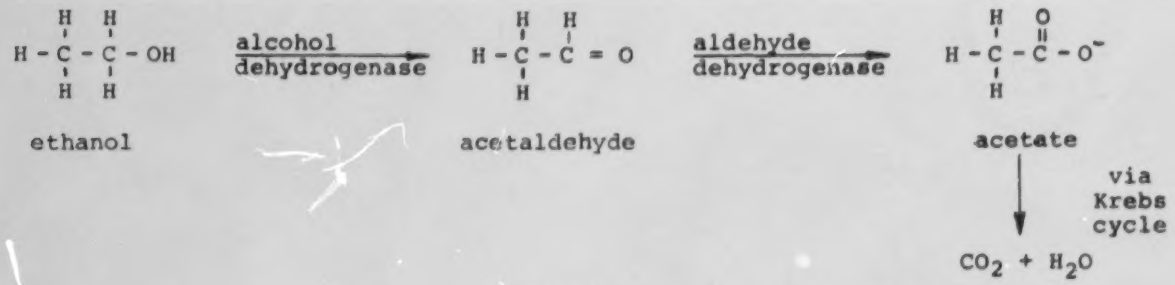
4. Information on cirrhosis of the liver may be found in Science Unit III, Instructor's Manual, pp. 70-71.

5. ST-19 and 20 are lengthy, since they provide a great deal of information for use in Biomedical Social Science. You may wish to advise your class that you will hold them responsible for only certain parts of these sections.

6. In the discussion of the effects of alcohol, you may wish to remind students that alcoholic beverages may trigger seizures in epileptics (as discussed in Lesson 3). Another consequence of alcohol use that you may wish to mention is its diuretic effect.

7. In Sections 19-3 and 19-4, there is reference to varices (varicose veins). You may wish to refer students to an earlier discussion of varicose veins in Unit III, ST-2.

8. Students may want to know what happens to alcohol biochemically after it is absorbed. Amost all of the alcohol ingested is converted to CO_2 and water with the release of energy. The metabolic steps are shown below.



9. In Section 19-4 there is a table describing the stages of the alcohol-withdrawal syndrome. The names were not given for these stages because the section is already lengthy, and some of the names would require additional explanation. More detailed information on the alcohol-withdrawal syndrome follows.

INFORMATION ON THE ALCOHOL-WITHDRAWAL SYNDROME:

The alcohol-withdrawal syndrome includes five states, which occur in a predictable sequence. (See table following Section 19-5.) The first state is called alcoholic tremulousness. It includes tremors--"the shakes," or "the jitters"--combined with irritability and gastrointestinal symptoms such as nausea and vomiting. This is the most common state of alcohol-withdrawal syndrome. The disorder typically appears in the morning following several days of hard drinking. A few drinks will relieve the symptoms, but the same symptoms will recur the next morning. If alcohol is withdrawn completely the major symptoms will subside within a few days as the body reestablishes homeostasis, but the patient will not recover completely for another 10 to 14 days.

The second state is called alcoholic hallucinosis. It may include disturbed sleep and bad dreams, distorted perceptions of familiar objects, and true visual hallucinations: seeing things that aren't there. Alcoholic hallucinosis occurs in about one fourth of the patients with alcoholic tremulousness.

The third state is auditory hallucinosis: hearing things that aren't there. What is heard is usually voices, and the voices are usually those of people familiar to the patient. The voices appear to come from behind the door, from the corridor or through the wall. In most patients the symptoms last a short time, from a few moments to a few days. In some patients the disorder persists for weeks or months, and in a few it becomes chronic.

The fourth state is called alcoholic epilepsy, also known as "rum fits." It consists of major generalized convulsions with loss of consciousness. The seizure usually occurs within two days after the patient stops drinking, then goes away. There may be only one seizure, but usually there are several. Many patients who suffer alcoholic epilepsy go into delirum tremens (see below) within a day or two after the seizures stop.

Delirium tremens is the fifth state. The symptoms of "DT's" include profound confusion, delusions, vivid hallucinations, tremor, agitation and sleeplessness, along with dilated pupils, fever, increased heart rate and profuse perspiration. In most cases the disorder lasts a few days and ends abruptly when the patient falls into a deep sleep, from which he awakens lucid, quiet, hungry and exhausted. About one case in seven ends in the death of the patient, often due to the combination of delirium tremens and some other disorder.

INFORMATION ON LABORATORY ACTIVITY 19:

TEACHING NOTES:

1. The purpose of this activity is to provide students with an opportunity to

test the action of a known antibiotic producer, Penicillium, against bacteria. It is interesting to compare the results of this test with tests of soil molds other than Penicillium (LA-16) and with tests of paper discs impregnated with the drug penicillin (LA-20).

2. Anticipated time: one period and part of a second period to observe plates.

3. The method of testing living Penicillium mold rather than penicillin is not the way in which antibiotic action is normally tested. Therefore, variables are introduced in this method which will affect the results. For example, the amount of penicillin the mold produces is determined in part by the age of the mold. Other variables that will affect the results include the age of the bacteria, their sensitivity to penicillin, and even whether the bacteria are penicillin-resistant mutants. To provide a greater chance of success, this activity calls for using two species of bacteria. A ring should occur with at least one. The results of tests run in our laboratory are given in "Anticipated Results."

4. The following options are available.

a. To grow more Penicillium, Penicillium can be transferred onto nutrient-agar plates for further culturing. Use forceps to spread a chunk of the mold over the surface of a nutrient-agar plate. Incubate in a dark place at room temperature. It takes 3 to 5 days for significant growth to appear.

b. You or a student may enjoy preparing an agar medium that Penicillium grows especially well on: potato-dextrose agar. It requires agar agar, which is different from nutrient agar and may be purchased in some health-food stores as well as from biological supply houses.

Wash a potato and dice it with the skin, boil it in 400 to 450 ml water on a low simmer for 30 minutes. Filter through cheesecloth to obtain 300 ml of liquid. Add 7.5 g dextrose (glucose) and 6 g dry agar agar to the liquid and boil to dissolve the agar. Mix while heating. Dispense into test tubes, cap the tubes and autoclave. Use the tubes to pour agar plates.

MATERIALS: (for 15 set-ups)

- plate culture of Penicillium notatum
- materials for sterile nutrient-agar tubes (see Preparation of Materials for LA-16, page 92 includes 4.65 g nutrient-agar powder and 15 test tubes with caps)
- 15 Petri dishes, sterile
- 5 to 10 hot water baths
- germicide
- 15 glass-marking pencils
- 15 beakers, 250-ml
- 15 forceps
- materials for broth-culture tubes of bacteria (see Preparation of Materials for LA-16, page 94 includes 0.6 g nutrient-broth powder, 10 test tubes with caps, and cultures of S. marcescens and S. aureus)
- 15 packets of sterile cotton balls wrapped in aluminum foil
- 100 ml ethyl alcohol (70 to 90%), denatured, with cups or beakers for distribution
- aluminum foil for disposal of used cotton balls
- 15 gas burners
- incubator
- 15 mm rulers

PREPARATION OF MATERIALS:

The table in Preparation of Materials for LA-16 shows the items requiring sterilization by autoclaving. Students can do much of the preparation themselves: such steps are indicated by an asterisk in the directions.

Broth-Culture Tubes of Serratia marcescens and Staphylococcus aureus: The preparation of broth cultures is described in Preparation of Materials for LA-16. For this activity, two to five broth cultures of each bacterium are recommended for a class of 30 students. (Note: the instructions in LA-16 are for only one type of bacterium.) Broth cultures used in LA-16 may be reused for this activity if they have been stored under refrigeration for no longer than one week.

Sterile Nutrient-Agar Tubes: The preparation of nutrient agar is described in Preparation of Materials for LA-16. The quantity of nutrient-agar powder specified in the Materials list (4.65 g) is sufficient to prepare 150 ml of agar, enough for 15 tubes.

ANTICIPATED RESULTS:

Tests in our laboratory showed no zone of inhibition with Serratia marcescens and one 5 mm wide with Staphylococcus aureus. In a second test, another species of Penicillin produced a zone of inhibition with Serratia marcescens, and none with Staphylococcus aureus. The zone in this case was 1 cm in width around the mold's perimeter.

ANSWERS TO DISCUSSION QUESTIONS:

1. Contamination of the agar may have occured each time the Petri dish cover was lifted, either to pour the agar or to inoculate it. It may also have occurred when the test-tube cap was removed to pour the agar.

2. Penicillin affects bacteria. Allergies are generally not caused by bacteria.

3. The species of bacteria used may not be affected by penicillin; the Penicillium mold may not have produced enough penicillin.

4. The kind of bacteria causing the disease may be different from the kind in the plate. Also, the penicillin may be quickly excreted by the animal or metabolized into an inactive chemical.

LESSON 20: (A) PSYCHOACTIVE DRUGS

(B) REVIEW

RATIONALE:

This lesson discusses opiates, cocaine and marijuana. Like alcohol, these drugs have or have had medical uses. These drugs are also important to medicine because their nonmedical use may cause problems that health-care providers must treat.

OBJECTIVES:

The student will:

- describe medically useful pharmacological properties of opiates and cocaine.
- discuss habituation, addiction, tolerance and withdrawal in relation to opiates, cocaine and marijuana.
- list the major health problems associated with use of opiates and cocaine.
- test for antibiotic activity by the paper-disc method.

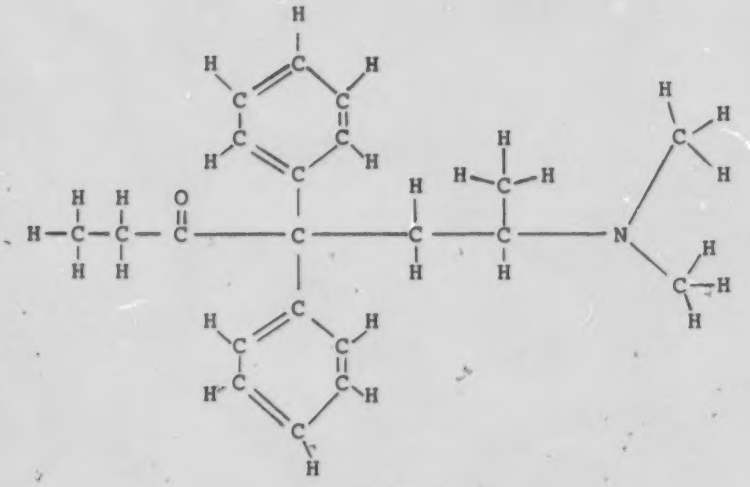
SEQUENCE: ST-20; LA-20; Review Set 20

SUGGESTIONS:

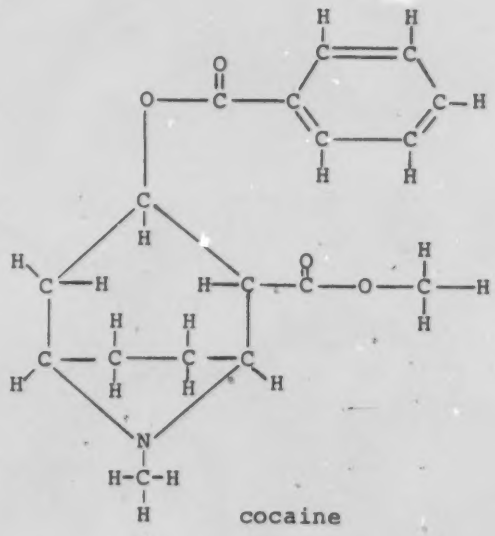
1. There is a "floating" lesson on evaluation of drug studies provided at the end of Biomedical Social Science, Unit V. It is intended for presentation soon after this lesson. You should coordinate your schedule with your Social Science colleague.

2. The students may find a speaker from a drug-rehabilitation center interesting. Look in the Yellow Pages of the telephone book under "Drug Abuse Information and Treatment Centers" or Drug Addiction Information and Treatment Centers" for possible sources of speakers.

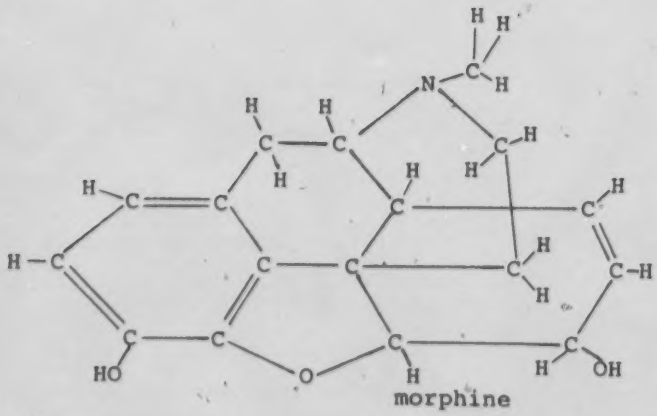
3. The chemical structures of the psychoactive drugs discussed in ST-20 are complex, yet they may be of interest to some of your students. Four are shown below.



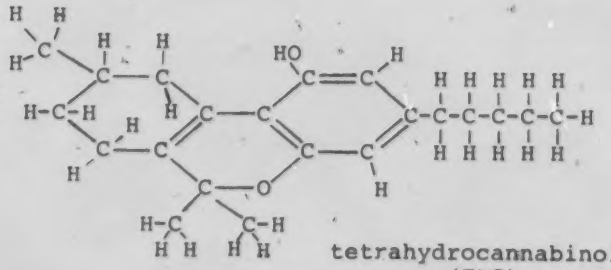
methadone



cocaine



morphine



tetrahydrocannabinol (THC)

4. Students may wish to learn more about the effects of heroin overdose. There is some confusion, because there is evidence that not all deaths attributed to heroin overdose are really due to this cause. This subject is discussed further on the following page.

5. The literature on marijuana is also confusing. Some published studies of the effects of marijuana on users have reached conclusions that are not valid. Some of the fallacies in such studies are summarized in the section headed "Information

on Marijuana." You may wish to describe to your students some of these studies and ask them to identify ways in which the experimental procedures could have been improved.

INFORMATION ON MARIJUANA:

Section 20-8 mentions studies of opiate addicts from which it has been concluded that marijuana use promotes or encourages opiate use. The Student Text points out the nature of the fallacy. The same fallacy sometimes influences conclusions drawn from studies of other unusual populations. For example, a study of prison inmates who had used marijuana found that a large percentage of them had committed a violent crime while under the influence of marijuana, and it was concluded that marijuana use promotes the commission of violent crimes. Several studies of mental-hospital patients have found that former marijuana users in the population under study are mentally ill, and it has been concluded that marijuana use leads to mental illness.

Less glaring errors in research design occur in other marijuana studies. Many studies have failed to include control subjects (who smoke placebos). The use of control subjects allows the experimenters to distinguish between the effects of a subject's ingesting THC and the effects of the subject's thinking he has ingested THC. Many controlled studies have failed to use double-blind designs, in which neither the subject nor the experimenter knows whether the subject is smoking marijuana or a placebo. The double-blind design ensures that the observer's questions and observations will not be influenced by knowledge that the subject really is (or really is not) under the influence of the drug.

Many studies have used such small numbers of subjects that the results of the studies could not reasonably be generalized to any larger population; physicians' published reports on patients whom they have seen in clinical practice often suffer from this fault. Some studies have failed to distinguish between subjects who are experienced marijuana smokers and subjects who are not. The importance of this distinction in marijuana studies is illustrated by the fact that experienced users often become euphoric or silly when they smoke a placebo. This placebo effect suggests that experienced users may have learned that it is somehow appropriate to become euphoric or silly when smoking marijuana; these effects may not be entirely due to the pharmacological properties of the drug.

Many marijuana studies have been conducted with essentially unknown quantities of the drug. Without chemical analysis it is impossible to know how much THC is in a given sample of marijuana. Until recently it was not even known how much of the THC in a given marijuana cigarette actually enters the smoker's lungs. (Recent studies have shown that about 50% of it is consumed.) In addition, the process of smoking a cigarette is different from one person to another; even with controlled doses of THC in the cigarettes, it is hard to know how much a particular individual gets into his or her lungs.

Finally, there is a lack of long-term studies of marijuana use. Many studies of chronic marijuana users have turned up a variety of alarming observations--poor physical health, criminal behavior, poor mental health, poor job performance, poor academic performance and so on. These findings themselves do not reveal much about the actions or effects of marijuana unless it is known that the subjects lacked these difficulties before they became marijuana smokers. Properly designed long-term studies would be able to distinguish between undesirable conditions that appeared after the subject began using marijuana and those which existed, or had a large potential for occurring, before the subject began using the drug.

The long-range health implications of chronic use of marijuana remain a question mark and there is evidently a need for valid research studies on this subject. In 1976, the National Institute on Drug Abuse (NIDA) issued its fifth annual report to Congress on marijuana research. Dr. Robert L. DuPont, the director of the NIDA, presented the report to Congress. While he advocated a liberalization of marijuana laws, he also indicated his concern about possible adverse effects of this drug. Some of DuPont's views on marijuana were summarized in an interview printed in the journal Science (Vol. 192, p. 647, 1976). When asked to summarize the marijuana report, he said:

"People are looking for simple statements that marihuana is safe or that it is dangerous, and the report defies that kind of summary. But there is a broad range of biological concerns reflected in the report, from the decrease in testosterone levels and effects on cell-mediated immunity to bronchitis and the potential for cancer. There is a growing concern about the seriousness of these negative health effects-although they are something less than has been searched for by many, such as some tremendous evidence that marihuana users' ears fall off or that their noses turn green, or something like that. Also, we have overlooked the problems of marihuana intoxication in the past. They are related most urgently to driving performance, but they are also related to work performance, to studying and to interpersonal relations--to the activities where, we are aware, most of the problems of alcohol are concentrated. We've just ignored that in the past discussion of marihuana's health hazards."

INFORMATION ON HEROIN OVERDOSE:

In 1970 over 80% of the deaths of heroin addicts in New York City were attributed to overdose. There is some evidence, however, that the conditions under which heroin is used contributed significantly to most of these deaths, and that many of these deaths were not due to overdose at all. It is, of course, possible for an individual to take an overdose of heroin and die from it, particularly when the heroin is from the black market and the addict has no means of finding out how strong it is. A person whose tolerance for heroin allows him to inject a large quantity of a mixture that is only 4% heroin may die if he injects an equal quantity of 40% heroin; and if his supply is from the black market, he may not know which he is injecting.

It is also possible to die of an overdose of heroin by building up a tolerance to large doses of heroin, then withdrawing, then injecting the same amount as before. The tolerance for the drug's depressant effects rapidly disappears as the addict goes through withdrawal. If his habituation, or craving, for the drug leads him to begin using it again, he must start with a smaller dosage than he was accustomed to before withdrawing.

Many addicts have died of overdose in one or the other of these ways. But there is also evidence that many of the deaths previously ascribed to overdose were actually caused in other ways. In 1969, the Deputy Chief Medical Examiner of New York City made the following observations at a meeting of an AMA committee.

1. The packets of heroin found near the bodies of dead addicts do not usually contain abnormally high percentages of heroin.

2. Syringes used by the addicts immediately before they die do not usually contain an abnormally potent mixture.

3. The urine of dead addicts usually does not contain levels of heroin consistent with the diagnosis of overdose.

4. The tissues near the site of the fatal injection do not usually contain high levels of heroin.

5. Almost all those addicts who die of overdose are experienced users, which implies that they would be more likely to be able to identify an abnormally potent mixture and therefore less likely to take a dangerously large dose than would a new user.

6. Addicts usually inject heroin in groups, but it is rare that more than one addict dies in such a situation.

Further evidence that overdose is not so often the cause of death as has been suggested is the fact that most "overdose" deaths are characterized by suddenness of death and pulmonary edema. Death due to overdose usually occurs over a period of an hour or more, not suddenly, and it is seldom accompanied by pulmonary

edema. It has been suggested that "overdose" deaths with these characteristics may actually be caused by poisoning with quinine, a substance often used to cut black-market heroin before it is sold. It is also possible that such deaths are caused by allergic reactions to heroin, although such reactions are rare.

Another possible cause of deaths by "overdose" is the combined pharmacological effects of heroin with other depressants, notably barbiturates and alcohol. An addict who has been unable to procure any opiate drug may use barbiturates or alcohol to take the edge off his withdrawal symptoms. If he obtains some heroin and uses it while under the influence of either of these two drugs, then the quantity of heroin that he has been accustomed to using may be sufficient, in combination with the other drug, to cause death.

The fact that some or many "overdose" deaths blamed on heroin are actually due to other causes should not be interpreted to suggest that heroin is a "safe" drug. The health problems associated with heroin have already been discussed in ST-20.

INFORMATION ON LABORATORY ACTIVITY 20:

TEACHING NOTES:

1. The purpose of this activity is to test the effectiveness of various antibacterial agents in inhibiting the growth of bacteria. Discs containing antibiotics or antibacterial agents are placed on a field of growing bacteria. The effectiveness of the antibacterial agent is assessed by examining the areas around the discs where bacterial growth has been inhibited. Similar procedures are used in clinical laboratories where antibiotic agents are used to identify unknown bacterial strains taken from a patient.

2. Anticipated time: one to two periods. One day of incubation is also required, plus about ten minutes on the second day for examination of the cultures.

3. The activity may be augmented by increasing the number of antibacterial solutions.

4. The choice of the antibacterial liquids is left to the instructor. A variety of antiseptics and disinfectants may be used. Examples include merthiolate, iodine solution, bleaches, household cleaning solutions and antibacterial soaps. The antibacterial effectiveness of a number of mouthwashes could also be tested--some mouthwashes may show no inhibition of bacterial growth. The students may wish to bring in their own solutions for testing.

5. Note that the broth cultures of bacteria must be prepared at least one day in advance of the activity.

6. The use of an incubator when growing the bacteria in Petri dishes is not absolutely necessary. The bacteria grow adequately at room temperature although an extra day or two may be required before obtaining final results.

7. If cost or availability of materials is a problem, the activity may be simplified. As examples, the students might be instructed to work in pairs, or only one type of bacterium might be tested instead of two.

8. Students need not be concerned if the Serratia marcescens colonies become white after incubation instead of red. This species does not make the red pigment when grown at warm temperatures.

9. You may wish to maintain the bacterial cultures used in LA-16 to 20 since the Genetics Unit also requires bacteria. However, to do this, the bacterial cultures will have to be kept alive by periodic transfers. The transfer process is done by placing a loopful of bacterial growth into fresh sterile nutrient broth. Incubate the new tube for 48 hours. The turbidity will increase markedly if the culture is viable. (The old one can be discarded.) About once a month, repeat the process. By means of such a "chain" of monthly transfers, a culture can be kept going indefinitely, until needed.

MATERIALS: (for 30 set-ups)

- materials for broth-culture tubes of bacteria (see Preparation of Materials for LA-16, page 94 --includes 0.6 g nutrient-broth powder, 10 test tubes with caps, and cultures of S. marcescens and S. aureus)
- materials for sterile nutrient-agar tubes (see Preparation of Materials for LA-16, p. 92--includes 18.6 g nutrient-agar powder and 60 test tubes with caps)
- 60 Petri dishes, sterile
- several pieces of filter paper
- 2 antibacterial liquids (see Teaching Note 4)
- 60 streptomycin antibiotic discs
- 60 penicillin antibiotic discs
- aluminum foil
- autoclave
- 2 to 5 hot-water baths
- incubator
- germicide
- 100 ml ethyl alcohol (70 to 95%), with cups or beakers for distribution
- 15 forceps
- 15 glass-marking pencils
- 15 test-tube holders
- 15 gas burners
- absorbent cotton

PREPARATION OF MATERIALS:

The items to be prepared and autoclaved before class are the following.

1. ten test tubes of nutrient broth, for preparing the broth cultures
2. test tubes containing 10 ml of nutrient agar--two test tubes per student
3. cotton balls in aluminum-foil packets--one packet per pair of students
4. filter-paper discs in aluminum-foil packets--one packet per pair of students

Broth cultures of Serratia marcescens and Staphylococcus aureus: The preparation of broth cultures is described in Preparation of Materials for LA-16. For this activity, five broth cultures of each bacterium are recommended for a class of 30 students. (Note: the instructions in LA-16 are for only one type of bacterium.) The broth cultures used in LA-16 may be reused for this activity if they have been stored under refrigeration for no longer than one week.

Nutrient agar: The preparation of nutrient agar is described in Preparation of Materials for LA-16. The quantitiy of nutrient-agar powder specified in the materials list (18.6g) is sufficient to prepare 600 ml of agar, enough for 60 tubes.

Sterile cotton balls: Preparation of sterile cotton balls is described in Preparation of Materials for LA-16.

Sterile filter-paper discs: Filter-paper discs may be punched out with a paper punch. They should be approximately one-quarter inch in diameter. Wrap 20 discs in aluminum foil in such a way that the foil can be easily unfolded. One such packet is sufficient for two students. Autoclave.

ANTICIPATED RESULTS:

In our laboratory, we found the penicillin did not inhibit the growth of Serratia marcescens, but showed a zone of inhibition with a radius of 19 mm on a colony of Staphylococcus aureus after 24 hours of incubation. Streptomycin caused zones of 8 and 11 mm, respectively, for Serratia marcescens and Staphylococcus aureus.

ANSWERS TO DISCUSSION QUESTIONS:

1. Streptomycin is most effective against Serratia marcescens. Penicillin is most effective against Staphylococcus aureus.

2. Penicillin shows no inhibition (under the conditions used) of the growth of Serratia marcescens. Of the two antibiotics, streptomycin is less effective in preventing the growth of Staphylococcus aureus.

3. With increasing distance from the discs the concentration of the antibacterial agent decreases until it is low enough to permit bacterial growth. The amount of bacterial growth increases with decreasing concentrations of the antibacterial agent.

4. The relative effectiveness of the liquid antibacterial agents depends upon the agents chosen.

5. The diameters depend on how fast the antibacterial agents diffuse over the agar, the concentration of the agents and the effectiveness of the agents in inhibiting bacterial growth.

6. A number of reasons are possible. The organism that grows on a Petri dish may not be the organism that is causing the disease. Also, conditions in the human body (e.g. pH, temperature and available nutrients) are different from those on the Petri dish. In addition, the antibiotic may be excreted too quickly, or broken down during digestion. Consequently, the results of a Petri-dish test may not always reveal the best antibiotic for treatment of the disease.

KEY--REVIEW SET 20:

1. Plant drugs: reserpine, digitalis, quinine, morphine, cocaine, atropine, etc.

Animal drugs: thyroxin, estrogen, insulin, epinephrin, oxytocin, cod liver oil, pralidoxime, etc.

2. Penicillin prevents bacteria from constructing a normal cell wall during cell division. The resultant cell walls are not strong enough to resist osmotic pressure; the cells burst and die.

3.

analgesic - C	sedative - B
cathartic - A	stimulant - F
depressant - E	vasodilator - D

4. Oxidizing agents such as chlorine. Chlorine is converted to hypochlorite ions which, in turn, inactivate enzymes required for bacterial metabolism.

Alcohols denature bacterial proteins.

Formaldehyde prevents bacterial growth. (It denatures proteins.)

Salts or sugars at high concentrations prevent bacterial growth.

Detergents and soaps dissolve the bacterial cell membrane by osmotic effects.

Fluoride makes the enamel of the teeth more resistant to bacterial attack.

Heat kills bacteria. (It denatures proteins.)

5. Patient's symptoms, medical history, data from a physical examination, data from laboratory tests.

6. a. Improvement in a patient who has received treatment (such as drug therapy with a placebo) that is not really chemically or physically effective.

b. A placebo may be used as a control in experiments on the effects of drugs. Two other, more controversial and less common uses are the following.

A placebo may be prescribed for a known condition that cannot be cured by drugs.

A placebo may be prescribed for an undiagnosed condition that does not appear serious enough to warrant extensive testing.

7. Answers will vary. See Section 18-3.

8. a. CNS depressant, sedative-hypnotic; general anesthetic in large doses; CNS stimulant in small doses.

b. malnutrition, cirrhosis of the liver, esophageal varices, neural damage.

9. Alcohol--causes habituation and addiction, tolerance and withdrawal symptoms, when used chronically in large doses.

Opiates--cause habituation and addiciton, tolerance and withdrawal symptoms, when used chronically in large or small doses.

Cocaine--causes habituation; whether it causes addiciton, tolerance and withdrawal symptoms is debatable.

Marijuana--does not cause addiction; whether it causes habituation is debatable; tolerance or withdrawal symptoms unlikely.

LESSON 21: WAVES AND SOUND

RATIONALE:

Our senses of hearing and vision function to interpret energy transmitted in the form of waves. ST-21 focuses on the different kinds of waves, i.e., transverse and longitudinal. In LA-21, Part I, the students generate traveling and standing waves in slinkies. This part of the activity provides students with the opportunity to generate both longitudinal and transverse waves. The frequencies and wavelenghts involved are also amenable to crude measurement. In LA-21, Part II, the students have the opportunity both to give and recieve a pure-tone audiometric test. This test is a widely used clinical test, and different kinds of results point to different causes of hearing loss.

Certain wave terminology is introduced in this lesson which will be used throughout our study of sound and optics. Hearing and vision are included in Unit IV because they provide much of the sensory input to our brains and in turn provide the basis for a large share of our responses to the surrounding environment.

OBJECTIVES:

The student will:

- describe the difference between transverse and longitudinal waves.
- state whether sound waves are transverse or longitudinal.
- describe the pure-tone audiometric process.
- calculate the wave speed for different stretched lengths of a coiled spring.
- conduct a pure-tone audiometric test.

SEQUENCE: ST-21; LA-21

SUGGESTIONS:

1. As indicated in the Introduction to this book, the sequence beginning with this lesson should not be presented until Mathematics Lesson 25 has been completed.

2. Part IA of LA-22 involves making equipment which requires glue to dry overnight. You should read LA-22 now and, if time permits, begin in Part IA of LA-22 during this class period. Otherwise the viewing of the eardrum will have to be postponed for a day.

3. To minimize equipment needs, you may wish to have different groups of students work simultaneously on LA-21, Parts I and II, LA-22, Parts I and II and LA-23. This is feasible, provided that ST-21, 22 and 23 have been read in advance.

INFORMATION ON LABORATORY ACTIVITY 21:

PART I: MAKING WAVES WITH A SLINKY

TEACHING NOTES:

1. The purposes of this activity are: (1) to reinforce wave terminology, i.e., frequency, wavelength, period and amplitude; (2) to introduce the ideas of standing waves, nodes and antinodes; (3) to use the technique of setting up standing waves to determine wavelength and frequency and finally the speed of wave propagation.

2. Anticipated time: 1 period.

3. The slinkies around which this acitivty was designed measure 6 cm in height x 8 cm in diameter when collapsed. If the collapsed length of your slinkies differs significantly from these dimensions, then the suggested 3-meter stretched length will not be ideal. For example, if your slinky's collapsed height is twice as high as ours, the slinky will not be taut enough when stretched to 3 meters and there will be significant difficulty in producing the longer wavelengths. If the collapsed height is less than 6 cm, then the slinky may be damaged when stretched to 3 meters. Before class begins you should experiment to determine a convenient stretched length for the generation of standing half waves. In general, the longer the slinky is stretched the easier it will be to generate standing half waves.

4. If you can't obtain 10 slinkies, you may want to divide the class into groups of appropriate size for the number of slinkies you can find. These groups can take turns using the equipment while the rest study the student text.

5. It will be desirable to demonstrate the generation of standing waves. Some pre-class experimentation may be necessary so that you can demonstrate the technique successfully.

6. Once the students have completed the calculations, the following points bear emphasis.

a. For a given stretched length of the slinky, the wave speed appears to be more or less constant.

b. Transverse waves and longitudinal waves have approximately the same wave speeds when the slinky is stretched to the same length.

c. The frequency for a standing wave appears to be independent of the stretched length of the slinky. For example, the frequency of a standing full wave appears to be about 14 cycles per 10 seconds regardless of length.

d. The ratio of speed to length is a constant.

$$\frac{\text{speed}}{\text{stretched length}} = \text{constant}$$

Or, equivalently, (speed) = (stretched length) (constant)

In other words, the longer the slinky, the faster the waves move.

7. (Optional) Use some error analysis to show that the speeds calculated from the lower frequencies have more uncertainty. For example, assume an absolute uncertainty of 1 stroke for the stroke count and .5 sec for the uncertainty in the time measurement. Recall that relative error of the quotient

$$\frac{13 \pm 1 \text{ strokes}}{10 \pm .5 \text{ seconds}}$$

is the sum of the relative errors of the numerator and denominator.

The relative errors are

13 ± 1	relative uncertainty 8%
10 ± .5	relative uncertainty 5%
	relative error of quotient 13%

In general, the constant absolute error of the numerator becomes a smaller relative error as the numerator increases.

For example,

Quotient	Relative Error
$\frac{13 \pm 1}{10 \pm .5}$	12.7%
$\frac{22 \pm 1}{10 \pm .5}$	9.5%

Practically speaking, the assumption of a constant 1-cycle absolute error of the denominator breaks down when the frequency goes over about 3 cps. It becomes increasingly difficult to get an accurate count of the cycles. They come too fast.

If you need to brush up on your error analysis, refer to Sections 1 through 6 of Mathematics Unit II. Alternatively, you may want to request the Mathematics instructor to make these points in his or her class.

MATERIALS: (for 10 set-ups)

10 slinkies masking tape

SAMPLE RESULTS:

	Number of Strokes	Time Interval (sec)	Stretched length (meters)	Number of standing waves	$f \cdot \lambda$ = speed (m/sec)	$\frac{\text{(speed)}}{\text{(length)}}$
Transverse waves	14	10	3	1	4.2	1.40
	23	10	3	1.5	4.6	1.53
	13	10	2	1	2.6	1.30
	22	10	2	1.5	2.9	1.45
Longitudinal waves	15	10	3	1	4.5	1.50
	22	10	3	1.5	4.4	1.47
	14	10	2	1	2.8	1.40
	22	10	2	1.5	2.9	1.45

$$\text{frequency} = \frac{\text{(number of strokes)}}{\text{(time interval)}}$$

$$\text{wavelength} = \frac{\text{(stretched length)}}{\text{(number of standing waves)}}$$

$$\text{speed} = \lambda f$$

ANSWERS TO PROCEDURE QUESTIONS:

1. The reflected wave will have a shape opposite to the incident wave. In other words, if the incident wave looks like a peak, the reflected wave will look like a valley and vice versa.

2., 3. The wave will typically reflect four or five times for both kinds of waves.

4. See Sample Results and Teaching Notes #6 and #7.

PART II: PURE-TONE AUDIOMETRY

TEACHING NOTES:

1. The purpose of this activity is to give each student a chance to both administer and take an audiometric test.

2. Anticipated time: Thirty to forty minutes for each pair of students.

3. Due to the time and equipment requirements of this activity, you should plan a schedule for pairs of students to use the equipment over the next few days until all have been tested. For example, you may be able to use any study hall periods the students may have, or request other teachers to excuse pairs of students from their classes.

4. Ideally, this activity should be performed with real audiometers. Of course, it will take a little advance preparation to obtain one or more of the instruments, but it should be possible. Almost every school district owns some audiometers for use in hearing-acuity screening of the student population. The trick will be to find out who has them. Check with the school nurse first. If this lead fails, ask your school district's consulting physician about them.

5. A quiet environment is essential to the success of this activity. Therefore, an environment other than the classroom is indicated. If your school nurse has an audiometer, perhaps the nurse's office could be used. Other possibilities include spare counseling offices, the principal's office, broom closets, a music practice room or a language listening room.

6. If you cannot locate audiometers, and are forced to use the BIP option, the hearing testing must be considered to be a simulation for at least two reasons. (1) Zero db on an audiometer is not the same sound pressure level for each frequency. It is adjusted to reflect the ear's differing sensitivities to differing frequencies. (2) A standard earphone is used for almost all audiometers. The response of the "medium-fi" stereo earphones is unlikely to be close to that of the standard. The standard earphone uses a standard cushion because the size of the air cavity between the earphone and the ear has a significant effect on how well a sound is heard. It is unlikely that a "medium-fi" earphone would use an identical cushion.

On the positive side, the BIP simulation will provide students with an opportunity to become familiar with both the audiometric procedure and what the procedure attempts to measure.

MATERIALS:

Either	Or
1 to 10 portable audiometers	2 BIP's
	1 pair of medium- to hi-fi stereo headphones
	24-gauge wire and wire stripper-cutters
	tape (any kind)

LESSON 22: THE EARS

RATIONALE:

To understand hearing it is necessary to understand some of the anatomy of the ear. ST-22 focuses on the functions of the different parts of the ear. In LA-22 the students perform the Rinné Test and construct an otoscope for viewing the eardrum. An analysis of the results of the Rinné test aids in the diagnosis of the hearing dysfunction, i.e., distinguishing between conduction and nerve deafness. By viewing the eardrum with an otoscope it is possible to detect infections of the middle ear.

OBJECTIVES:

The student will:

- state the functions of the eardrum, middle-ear bones, cochlea and basilar membrane.
- state how the basilar membrane responds to waves of different frequencies.
- interpret the results of the Rinné test.

SEQUENCE: ST-22; LA-22

SUGGESTIONS:

1. We have omitted much descriptive anatomy in an effort to simplify the explanation of the function of the ear. You may wish to give the students more terms than appear in the text. (See figures 1 through 4.)

2. The relationship $p = \frac{F}{A}$ is referred to in Section 22-3. It might be helpful to review the earlier treatment of pressure in Unit I, Lesson 13.

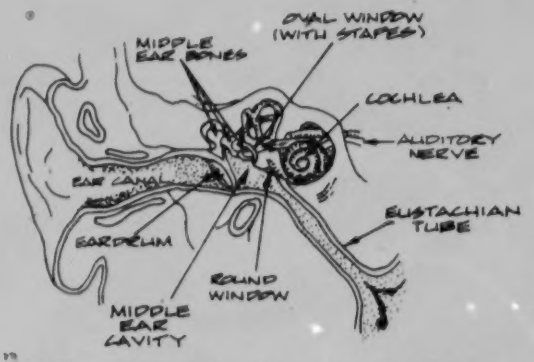


FIGURE 1: Overall cutaway view of the ear.

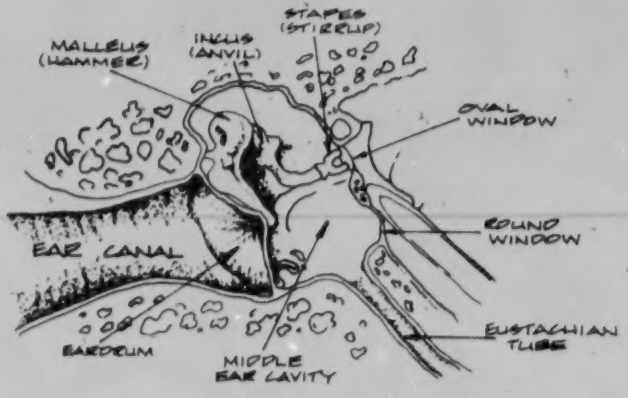


FIGURE 2: Cross-sectional diagram of middle ear and middle-ear bones.

INFORMATION ON LABORATORY ACTIVITY 22:

PART I: LOOKING INTO THE EAR

TEACHING NOTES:

1. The purpose of this activity is to acquaint students with the principles and use of the otoscope. The student will also visualize and identify the principal features of the eardrum.

2. Anticipated time: one-half period for Part IA; one period for Parts IB and IC.

3. Part IA, construction of the otoscope, must be done a day earlier than Parts IB and IC to allow the glue to dry.

4. It is recommended that each student make and have his own speculum used on him. This will eliminate the possibility of cross contamination.

5. It is suggested that half of the class complete Parts IB and IC while the other half is doing Part II. Upon completion of the procedure, each group can exchange equipment with a group that has performed the other part of the activity.

6. Part IB is a "dry run." It is very important that students master the technique before trying it out on a subject.

7. Before Part IC, it is suggested that you demonstrate the technique and go over the precautions. The ear canal is about 25 mm long. To prevent any possible injury to the drum, it is essential that the speculum never be introduced beyond the red mark, which is 20 mm from the small end.

8. Some of the students may have too much wax in their ears to permit a good visualization, so other students may need to be subjects more often than once.

9. The focal length of the hand lens must be at least 10 cm. The approximate focal length of a magnifier can be determined by focusing a light distant object on a piece of white paper and measuring the distance between the lens and the paper. If this distance is greater than about 16 cm, the eardrum may appear too small.

10. Some #222 lamps may not form a small, intense beam of light and should be replaced. In some cases the filament will be off center, and the lamp must be repositioned to correct for this.

MATERIALS: (for 5 otoscopes and 30 specula)

- 5 BIP's
- 5 hand magnifiers (2" to 3" diameter, focal length 10 cm to 16 cm)
- 5 #222 lens-end flashlight lamps
- 5 resistors, 10-Ω
- 10 sheets white paper, medium-weight
- 3 bottles white glue
- 15 scissors
- masking tape
- red-ink pen (or pencil)
- black-ink pen (or pencil)

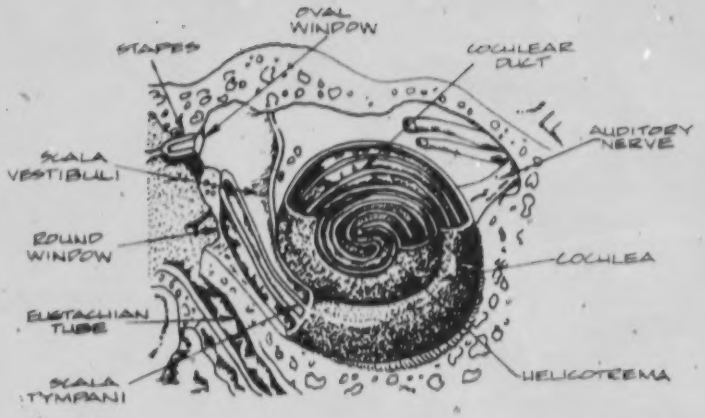
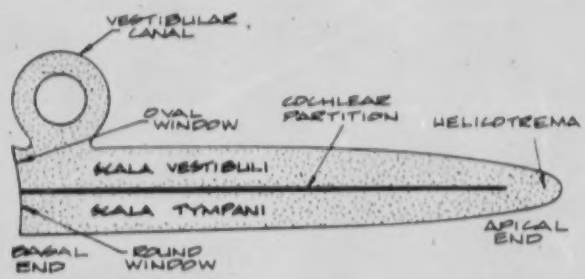
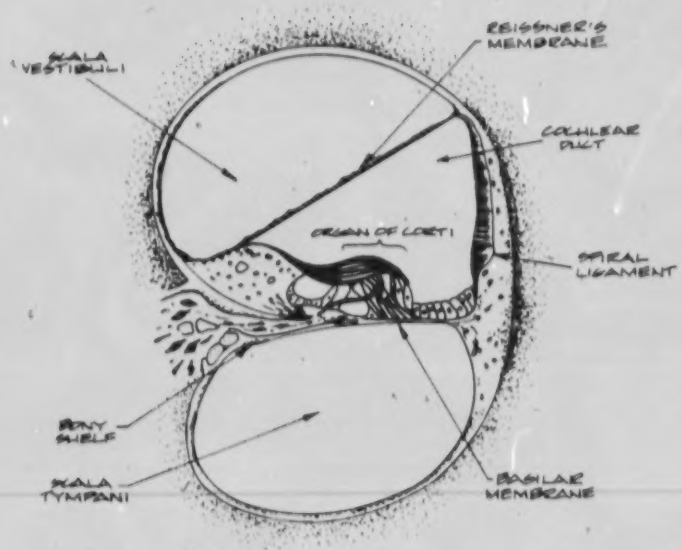


FIGURE 3: The cochlear portion of the inner ear.



(a)



(b)

FIGURE 4: Diagram (a) shows a longitudinal section of the unrolled coachlea. Diagram (b) is a cross section through the unrolled cochlea.

PREPARATION OF MATERIALS:

Prior to the activity, 24-gauge BIP wire must be soldered to the tip of each #222 light bulb. Strip approximately 1/8 inch of insulation from one end of a three-foot length of connecting wire. Solder the stripped end to the tip of the light bulb using a hot soldering iron. Although the tip of the light bulb is composed of a small blob of solder, it will probably be necessary to use a small amount of additional solder with flux to achieve an adequate connection.

PART II: THE RINNÉ TEST

TEACHING NOTES:

1. The purposes of this activity are to give the students an opportunity to experience bone conduction of sound and to perform a test used to distinguish between conduction and nerve hearing loss.

2. Anticipated time: Five to ten minutes per pair of students, depending on the number of tuning forks available.

3. There are limitations to the Rinné test. Unless there is a severe air-conduction loss, the patient will still hear better by air conduction than bone conduction. Normally the ear is much more sensitive to airborne sounds, and consequently, a slight air-conductive loss will not overcome this advantage. Therefore, if a patient hears better by air conduction, it does not necessarily mean that a known hearing loss is due to a sensory-neural impairment.

Another limitation involves the testing of a patient who has a severe sensory-neural loss in only one ear and normal or near-normal bone conduction in the other ear. For this particular ear the patient will report better hearing by bone conduction than air conduction. This would seem to indicate a conductive impairment. Of course, what might actually be happening is that the patient is hearing by bone conduction to the good ear. To eliminate this possibility the tester should introduce a masking noise to the good ear while testing the other ear.

MATERIALS: (for 5 set-ups)

5 tuning forks in the range of 256 cps to 2048 cps

5 rubber stoppers, one-hole

5 pencils

ANSWERS TO DISCUSSION QUESTIONS:

1. Since the subject can hear better by air conduction than bone conduction, this would tend to indicate that the loss is located in the cochlea.

2. Better hearing by way of bone conduction is the reverse of the normal pattern and suggests a dysfunction of the air-conduction pathway.

LESSON 23: COMMON HEALTH PROBLEMS AFFECTING THE EAR

RATIONALE:

Hearing is one of our most vital senses. Good hearing is usually necessary for our safety and economic health. It adds dimensions to communication. However, our ears are a common source of health problems, from early childhood to old age. Several health careers relate to health problems affecting the ear.

OBJECTIVE:

The student will:

- state at least four common causes of hearing loss.

·distinguish between conduction and perception impairments.

·describe the nature of an audiogram and list some of its uses.

·state how middle-ear infection occurs.

·describe how noise may affect our health.

·calculate the speed of sound when given the frequency and wavelength.

SEQUENCE: ST-23; LA-23

SUGGESTIONS:

1. You might wish to discuss ways of minimizing hearing loss due to industrial noise such as jackhammers, airport jet noise, etc. An industrial safety engineer would be a good guest speaker on this subject.

2. The role of noise as a health problem (apart from hearing damage) is a field needing further work. Selected students might be given a special assignment in the area. "Physiological Effects of Noise," Welch & Welch, Plenum Press, is a somewhat technical book on this subject but is full of interesting material.

3. You may wish to use some of the following informational points in classroom discussion.

a. Hearing aids have not been discussed in the Student Text. These solid-state devices are quite helpful in overcoming some types of moderately severe hearing loss. The audiogram helps to determine what kind of aid should be chosen. A hearing aid consists of a microphone, an amplifier and a transducer. The microphone converts sound energy into electrical signals. These electrical signals are amplified sufficiently to drive the transducer, which converts electrical signals back to acoustic energy. The transducer may be an air-conduction type that inserts into the ear canal or a bone-conduction type that fits against the mastoid process. The person who benefits most from a hearing aid has a "flat" conductive loss of 30 to 60 db. This individual will hear amplified speech with a minimum of distortion. In all cases, it is preferable that a hard-of-hearing patient get professional counseling at an audiology clinic rather than depend on a hearing-aid salesperson.

b. Middle-ear infection was once a scourge of early childhood, often leading to partial deafness and chronic infection. The problem has been drastically improved since the advent of antibiotics. Before antibiotics, mastoid surgery was sometimes necessary to eradicate infection that had penetrated into the bone.

c. Conduction impairments affect low frequencies the most. This is because low frequencies require more amplitude of movement of the eardrum or ear bones and if the drum becomes stiff or the bones ankylosed, the lower frequencies will not be transmitted as well.

d. There is a new technique for hearing testing called acoustic-impedance audiometry. This technique is different from pure-tone audiometry in that it does not require a subjective response. It is particularly helpful in determining the extent of damage due to middle-ear infection.

INFORMATION ON LABORATORY ACTIVITY 23:

TEACHING NOTES:

1. The purpose of this activity is to measure the speed of sound by the resonant method.

2. Anticipated time: One period.

3. A possible bottleneck in this activity may be the number of available stethoscopes. Try to obtain as many as you can. While students are waiting for the stethoscopes, they can perform other activities such as audiometry.

4. Ideally the resonant tube should be clamped to a one-meter ring stand. A

shorter stand can be used by placing the stand at the edge of a table with the tube extending below the edge.

5. Some students will have difficulty in finding the resonant points. The stethoscope can help if used to listen at the top of the resonant tube. Resonance cannot be heard if the stethoscope touches the resonant tube or the tuning fork.

6. The resonant tube has an open-end effect which makes the first resonant point slightly less than one-quarter wavelength. One empirical formula relates the wavelength of the sound (λ) to the length of the resonating air column (L) and the diameter of the tube (d) as follows.

$$\lambda = 4(L + 0.4d)$$

This activity avoids this complication by finding two or three resonant points and performing a subtraction which eliminates the end effect.

7. Tuning forks with low frequencies, such as 128, 256 and 288 cps, cannot be used in this activity, as it is written, without a resonant tube longer than the one specified here. But the low-frequency forks can be used if the student finds one resonant point and then makes the correction for the end effect just described.

8. In the Unit II Instructor's Manual, p. 182, we specified a 22-mm I.D., 30 cm long piece of tubing. These tubes might possibly be used if three of them could be fastened together in a watertight manner.

9. We have specified equipment for only half a class to reduce the equipment and set-up problems. All the class can perform the activity if the students are rotated in groups.

MATERIALS: (for 16 students)

- 4 resonant apparatus
- 4 tuning forks, 512 cps (or other frequency)
- 4 meter sticks
- 8 rubber bands, thin, medium-size
- 4 beakers, 250-ml (or larger)
- 4 stethoscopes
- 4 rubber stoppers, one hole, #4
- 1 or more thermometers

The resonant apparatus we have used consists of the following items.

- 90-cm length of clear acrylic plastic tubing, 2.5-cm O.D.
- 1-meter length of flexible tubing, 3/16" I.D.
- rubber stopper, one-hole, #4
- short length glass tubing (elbow or straight), 6-mm O.D.
- large funnel, to fit flexible tubing, approximately 10.5 cm in diameter
- ring stand (1-meter, if available)
- 3 ring-stand clamps

ANTICIPATED RESULTS:

The table on the following page gives the approximate air-column lengths for resonance using certain tuning-fork frequencies. The actual lengths will vary according to the air temperature and the diameter of the resonant tube. The lengths in the table have been corrected for the end effect of the recommended tube. This tube had an inside diameter of about 2.25 cm. Therefore, the end effect is .9 cm. Consequently all lengths in the table are about .9 cm shorter than the theoretical lengths. If you use a tube that has a smaller diameter, the end effect will be smaller.

The speed of sound in air (at one atm pressure and 20 °C) is approximately 331.5 m/sec. The row for 512 cps is what we obtained in our laboratory.

Tuning-fork frequency, f (cps)	Resonant Lengths of Tube (cm)		
	$\frac{\lambda}{4}$	$\frac{3\lambda}{4}$	$\frac{5\lambda}{4}$
128	64.0	--	--
256	31.5	--	--
320	25.0	77.0	--
341	23.5	72.0	--
384	20.5	64.0	--
427	18.5	57.5	--
480	16.5	51.0	85.5
512	15.5	47.5	80.0
1024	7.0	23.5	39.5

ANSWERS TO DISCUSSION QUESTIONS:

1. 25 mm

2. a. 500 cps b. 1500 cps c. 2500 cps

LESSON 24: SPEECH

RATIONALE:

The organs of speech production are introduced in ST-24, while the factors affecting the vibration rate of strings (and the vocal cords) are investigated in LA-24. Speech, of course, is of fundamental importance in almost all forms of human activity. In addition, a number of health professions are devoted to the correction of speech problems.

OBJECTIVES:

The student will:

- describe the speech-making process.
- state the source of energy in speech.
- state how the three different factors, effective length, linear density and tension, affect the vibrational rate of vocal cords and other "strings."
- distinguish between plosive and fricative speech sounds.

SEQUENCE: LA-24 (partial); ST-24

SUGGESTIONS:

1. Note that the discussion in ST-24 presumes that the students have completed at least a significant portion of LA-24, Part I, earlier. LA-24 is a long

activity which will probably take two periods to complete. The suggested order of presentation is as follows.

1st day: as much of LA-24, Part I, as time permits, followed by discussion of ST-24

2nd day: remainder of LA-24, followed by discussion of ST-25

2. We have omitted any mention of the neurological aspects of speech because of time and space considerations. However you may wish to point out that the feedback provided by being able to hear our own speech contributes greatly to the development and maintenance of speech skills. As evidence of this you can cite the difficulties with speech of people deaf from birth and the deterioration of speech of those who lose their hearing.

Another piece of evidence relates to a marijuana test. One test given to people who have smoked marijuana is to make them talk while hearing their voices played back to them with a 1/3-second delay. Inability to talk coherently in this situation (it is difficult for anyone, but more difficult for those under the influence of marijuana) illustrates the extent to which we normally rely on simultaneous feedback from our voices.

3. You may wish to mention other, less frequently used, sound-making mechanisms. For example, when we whisper, a hiss-like sound is produced by holding the vocal cords together without vibrating them. Some foreign languages use "clicks." They are produced by blocking the vocal tract at two points, sucking the air from between the two blocks and then re-opening the tract. Some foreigh languages use sounds generated during inhalation, but English uses only sounds produced during exhalation.

INFORMATION ON LABORATORY ACTIVITY 24:

TEACHING NOTES:

1. The purpose of this activity is to give the student experience with the variables that affect the resonant frequencies of strings.

2. Anticipated time: two periods.

3. In the Anticipated Results section data are given for three kinds of string, i.e., ordinary cotton packing string, 20-lb test monofilament and 8-lb test monofilament. Other kinds of line may be used with little effect on the attainment of the objectives of the lesson. Keep in mind that the heavier the line is, the more standing waves there will be at the lowest resonant frequency.

4. In addition to your "standard" supply of line (e.g., a roll of 20-lb test monofilament line), you should have small amounts of assorted "unusual" line--extension cords, rope, electrical wire, etc.--for students to experiment with in Part I, Step 17.

5. The C-clamps might be obtained from a shop teacher, if the physics laboratory doesn't have enough of an equivalent type.

6. The speakers are not part of the BIP accessory kit. They do not need to be completely functional for the purposes of this activity; the cones may be cracked or ripped. This suggests a source for the speakers--radio-television repair shops.

7. Do not expect all BIP-measured frequencies to agree. There is some variation between instruments.

8. Note that the Part II set-up requires two BIP's, and therefore only five set-ups are possible. Part II is quite short, so that it is feasible to have two student groups take turns using one set-up.

MATERIALS: (for 10 set-ups)

- 10 BIP's
- 10 meters of string
- 10 meters nylon cord, 20-lb test, monofilament
- 10 meters nylon cord, 8-lb test, monofilament
- 10 speakers, 4 to 16 Ω impedance, permanent-magnet type
- 20 C-clamps or equivalent
- 20 paper clips
- BIP wire(24-gauge) and wire stripper-cutters
- 20 alligator clips
- 10 meter sticks
- 10 balances
- assorted wires, ropes, etc., for Step 17, Part I
- 10 weight kits

ANTICIPATED RESULTS:

There is some error in the BIP dial; therefore, we have included for your information the resonant frequencies as measured by a highly accurate frequency counter.

TYPE	f_{BIP} (cps)	$f_{accurate}$ (cps)	λ (cm)	m (g)	linear density (g/m)
cotton packing string 60 cm effective length	110	107	60	500	1.26
	160	162	40	500	1.26
	210	212	30	500	1.26
	300	275	24	500	1.26
	360	329	20	500	1.26
	110	103	120	2000	1.26
	210	216	60	2000	1.26
	350	315	40	2000	1.26
	420	414	24	2000	1.26
	580	516	20	2000	1.26
20-lb test nylon monofilament 60 cm effective length	125	124	120	500	.20
	250	245	60	500	.20
	390	365	40	500	.20
	520	482	30	500	.20
	700	599	24	500	.20
	250	252	120	2000	.20
	520	500	60	2000	.20

TYPE	f_{BIP} (cps)	$f_{accurate}$ (cps)	λ (cm)	m (g)	linear density (g/m)
8-lb test nylon monofilament 60 cm effective length	210	206	120	500	.08
	420	415	60	500	.08
	700	620	40	500	.08
	420	417	120	2000	.08
	850	818	60	2000	.08
cotton string 30 cm effective length	110	105	60	500	1.26
	205	207	30	500	1.26
	350	307	20	500	1.26
	420	403	15	500	1.26
20-lb test 30 cm effective length	250	246	60	500	.20
	500	486	30	500	.20
8-lb test, 30 cm effective length	410	410	60	500	.08

ANSWER TO PROCEDURE QUESTION (Part I, Step 9):

The presence of the paper clip on the string will make the production of standing waves more difficult.

ANSWERS TO DISCUSSION QUESTIONS:

1. Lower.

2. It will gradually lower the pitch of our voices.

3. This prediction is approximately correct. The table below compares the fundamental frequencies observed when the effective length was halved.

	$f_{accurate}$		f_{BIP}	
	Fundamental Frequency		Fundamental Frequency	
m = 500 g	L = 60 cm	L = 30 cm	L = 60 cm	L = 30 cm
cotton string	(53.5)*	105	(55)*	110
20-lb test	124	246	125	250
8-lb test	206	410	210	410

* Although this frequency is unattainable with the BIP it may be estimated by dividing the λ = 60 cm harmonic frequency by 2.

4. Increases.

5. An increase in tension of our vocal cords will increase the pitch of our voice.

6. This prediction also seems to be borne out.

	$f_{accurate}$		f_{BIP}	
	Fundamental Frequency		Fundamental Frequency	
L = 60 cm	m = 500 g	m = 2000 g	m = 500 g	m = 2000 g
string	(53.5)	103	(55)	110
20-lb test	124	252	125	250
8-lb test	206	417	210	420

7. Smaller.

8. A thickening of the vocal cords will cause a general lowering of the pitch of the voice.

9. This prediciton also seems to be accurate.

	$f_{accurate}$	f_{BIP}
	Fundamental Frequency(cps)	Fundamental Frequency(cps)
Linear Density	L = 60 cm m = 500 g	L = 6 cm m = 500 g
string--1.26 g/m	(53.5)	(55)
20-lb test--.20 g/m	124	125
8-lb test--.08 g/m	206	210

10. This prediciton seems to be borne out, although not quite as accurately as the others.

m = 500 g L = 60 cm	Fundamental Frequency (cps)	Second Harmonic (cps)	Third Harmonic (cps)
string	(53.5)	107	162
20-lb test	124	245	365
8-lb test	206	415	620

LESSON 25: (A) ENGLISH SPEECH SOUNDS

(B) REVIEW

RATIONALE:

Any speech practitioner needs to know how the various English speech sounds are produced. ST-25 focuses on a very basic introduction to linguistics.

OBJECTIVES:

The student will:

- distinguish between voiced and unvoiced sounds.
- state how the vowel quadrilateral relates to English vowel sounds.

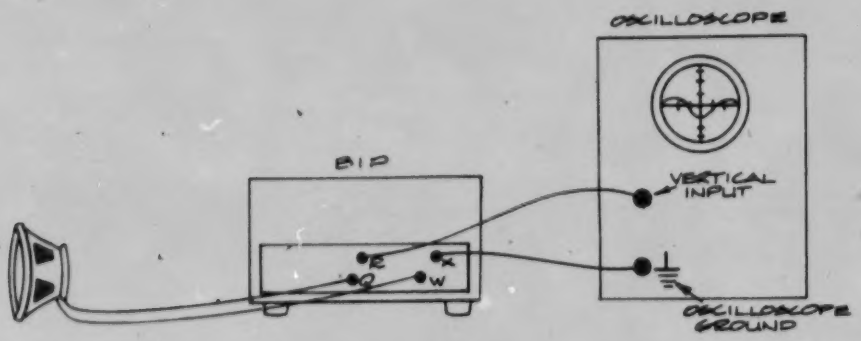
- explain how the vocal cords and vocal tract interact to produce frequencies up to 10,000 cps.

- generate beat and harmonic standing-wave patterns.

SEQUENCE: LA-24 (complete); ST-25; Review Set 25

SUGGESTIONS:

Both the spacing and values of the natural resonant frequencies of the vocal tract give vowel speech waves their characteristic shapes that in turn allow them to be distinguished when they are heard. The different wave shapes of vowels may be visualized with the aid of a BIP, speaker and oscilloscope. To perform this demonstration, arrange the equipment as shown below.



With this arrangement the speaker acts as a microphone and the BIP as an amplifier. The signal from the speaker may be amplified to various degrees by varying the "db" control of the BIP. With proper adjustment of the oscilloscope (be sure the "sync" feature is switched in), the characteristic wave shapes of the different pure vowels and fricative consonants may be displayed. The same vowel will have close to the same shape for different individuals. (Whistling also produces interesting wave shapes.) A good time to perform this demonstration would be after the discussion of ST-25.

KEY--REVIEW SET 25:

1. Energy.

2. Matter itself exists as waves.

3. Sight and hearing

4. We generate sound waves during speech for the purpose of communication.

5. Longitudinal.

6. An audiologist varies the pitch and amplitude of sound transmitted to a subject. The subject indicates the sound of lowest amplitude that is audible. In this way an audiologist determines the hearing thresholds for a subject for a standard set of frequencies.

7. Standing waves have a stationary location. Traveling waves move through space.

8. 660 meters/sec.

9. The auditory canal transmits sound waves from the outer ear to the eardrum. It also amplifies sound waves with frequencies that match its own natural resonant frequencies (about 4,000 cps).

10. The eardrum vibrates in response to sound waves that strike it. This mechanical vibration may then be picked up by one of the middle-ear bones.

11. The middle-ear bones transmit sound vibrations from the eardrum to the oval window. They also amplify sound waves of low amplitude and reduce the amplitude of sound waves of large amplitude.

12. The basilar membrane vibrates in response to sound vibrations in the fluid of the middle ear. Near the oval window the basilar membrane is stiff and vibrates most easily in response to the higher frequencies. Toward the end it is more flexible and vibrates more easily in response to the lower frequencies. Therefore, antinodes for higher frequencies occur closer to the oval window and antinodes for lower frequencies occur farther down the membrane. In this way, the basilar membrane sorts out frequencies along its length.

13. Riding on the basilar membrane is the organ of Corti. As the basilar membrane vibrates, the hairs of the organ of Corti collide with a membrane. These collisions stimulate the hair cells at the base of the hairs. Movement of the hairs causes action potentials to be generated by the hair cells.

14. Pitch information is generated as a result of the different locations of antinodes in the basilar membrane, depending upon the frequencies of sounds.

15. In the bone conduction phase of the Rinné Test the amplification function of the middle ear is by-passed. Thus a subject can hear a tuning fork longer by air conduction.

16. An observation of the eardrum may reveal a blocked ear canal, a punctured eardrum, an inflamed eardrum or perhaps a build-up of pus behind the eardrum.

17. a. Conductive. d. Conductive g. Conductive. j. Perceptive.

b. Perceptive. e. Conductive. h. Conductive. k. Conductive.

c. Conductive. f. Perceptive. i. Perceptive. l. Perceptive.

18. Prolonged exposure to loud noise.

19. 259 meter/sec.

20. 250 cm.

21. 275 cps and 825 cps

22. If the first resonant frequency is f, then all resonant frequencies will be given by the formula

f + 2nf, where n is a non-negative whole number. (This formula ignores end effects.)

23. The auditory canal and the vocal tract.

24. a. The longer the effective length the lower the fundamental resonant frequency.

b. The greater the tension, the higher the fundamental resonant frequency.

c. The greater the linear density, the lower the fundamental resonant frequency.

25. a. Effective length. b. Tension.

26. If f is the fundamental frequency, the formula (nf), where n is a positive whole number, will give all possible resonant frequencies.

27. a. Decrease. b. Decrease. c. Decrease.

28. By changing the tension in our vocal cords we voluntarily change the pitch of our voices.

29. Singer's polyp and laryngitis.

30. b, d and g.

31. f, θ, s and sh.

32. Generally, three.

33. They change.

34. English uses eleven pure vowels and five diphthongs.

35. During the articulation of a diphthong, the configuration of the vocal tract moves from one pure vowel to another.

36. Our vocal tract is a resonating air column that has its own resonant frequencies. As our vocal cords vibrate the vocal tract "rings" at its own resonant frequencies, which may go as high as 10,000 cps.

LESSON 26: INTRODUCTION TO LIGHT AND VISION

RATIONALE:

This is the first of 11 lessons concerned with the properties of light and the anatomy and physiology of the visual system. The sequence culminates with an activity involving the vision screening of elementary-school children. Diffraction is considered in this lesson because diffraction may be used to measure the wavelengths of different colors of light. And wavelength is as important in the study of light and vision as it is in sound, speech and hearing. Furthermore, the derivation reinforces some trigonometric ideas recently developed in Biomedical Mathematics.

OBJECTIVES:

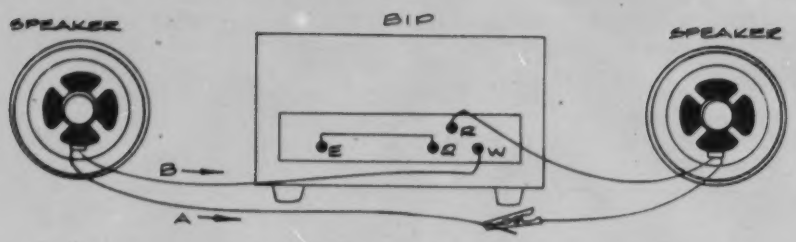
The student will:

- state at least one difference between light and sound.
- describe how differences in distance from two different wave sources lead to differences in phase relationships.
- state distance relationships that lead to "in-phase" and "out-of-phase" relationships.
- compute λ when given the distance between slits and the angular separation between bright diffraction lines.
- calculate the wavelengths of different colors of the spectrum.

SEQUENCE: ST-26; LA-26

SUGGESTIONS:

1. To set up the speakers and BIP as described in Section 26-4, make the connections indicated in the diagram on the following page.



To obtain the predicted patterns most reliably, the activity should be performed outdoors or alternatively in a large hall or gymnasium if the weather is inclement. Reflection of sound waves from walls will produce anomalous patterns. (Therefore, if the activity is performed in an auditorium or gymnasium, the equipment should be located in the center of the room.) We have obtained the predicted patterns with the BIP set for 1300 cps ("freq" dial at 130 and slide switch down) and the speakers separated by 50 to 100 cm; $\lambda \approx 25$ cm at this frequency.

In addition to connecting the speakers as shown, you will also have to make sure that the speakers are in phase electrically. In other words, you will have to ensure that the speaker cones are moving in and out in tandem instead of in a syncopated manner. There is a 50% chance that this will happen when they are first connected. To determine whether the speakers are in phase, listen at a point equidistant from both speakers. A local maximum should be located there. (By plugging one ear with a finger and moving your open ear slightly from side to side, you should hear the sound level fall off to either side of a point equidistant from both speakers. See Section 26, Figure 3.) If a local maximum is not located at this point, then the speakers are not in phase electrically. To reverse the electrical phase relationship of the speakers, reverse the electrical connections of one speaker. See the diagram above. Disconnect wires A and B. Then plug wire A into programming terminal W and connect wire B to the alligator clip.

When the speakers are set up properly, it is possible to locate positions where the waves from both speakers reinforce each other and the reverse, by plugging one ear and walking around. The locations will be most sharply defined in the neighborhood of one meter in front of the speakers. If too many students are wandering around in the field, once again anomalous patterns will be produced because of absorption, reflection and diffraction of sound waves by the students' bodies.

If you wish to quantify this activity, measuring equipment such as meter sticks, string or tape measures should be on hand.

2. You may wish to discuss the importance of having stereo speakers in phase electrically. If they are out of phase, then low tones especially from the two speakers will tend to cancel each other out. Stereo speakers may be phased in a manner similar to that used for the BIP speakers. One person listens to the low tones, while another reverses the connections of a pair of speaker leads.

3. Certain burglar alarm systems use an arrangement similar to the two-speaker-BIP arrangement described in Suggestion 1 to detect movement in a room. Instead of audible sound frequencies, however, ultrasonic frequencies are used. A moving object in the diffraction field will cause the intensity of the signal at a receiver to change. This change triggers an alarm. By having a student wander around in the diffraction field and other stationary students listen, this phenomenon can be directly experienced.

4. Use a ripple tank, if available, to demonstrate diffraction patterns. See PSSC Physics, D.C. Heath and Co., Boston, 1968, p. 285.

5. Light and dark diffraction lines may be seen by looking at the sky or fluorescent lights through two nearly closed fingers.

6. The derivation of the formula $\lambda = d \sin \theta$ is optional. (You may wish to omit this derivation.) No subsequent material depends upon the derivation. However,

much following material depends upon the use of the formula; therefore, we do not recommend omission of the problem set.

7. Your students may wish to investigate holography. A hologram is simply a picture of the interference patterns of an object, made with a monochromatic coherent light (e.g., a laser beam). You are seeing a simple hologram whenever you look at a diffraction pattern. Have the students punch a hole in a piece of paper with a thumb tack and look at a strong light through the hole. They should see a series of concentric rings, which are the hologram of a dot.

KEY--PROBLEM SET 26:

1. a. $\frac{1 \text{ cm}}{5{,}000 \text{ grooves}} = .0002 \frac{\text{cm}}{\text{groove}}$

   b. $2 \times 10^{-4} \frac{\text{cm}}{\text{groove}}$

   c. $2 \times 10^{-4} \frac{\text{cm}}{\text{groove}} \cdot \frac{10^7 \text{ nm}}{\text{cm}} = 2{,}000 \frac{\text{nm}}{\text{groove}}$

2. 4,000 nm/groove

3. 3,030 nm/groove

4. 2,500 nm/groove

5. 1,333 nm/groove

6. a. .0001 in/groove

   b. 1×10^{-4} in/groove

   c. 2.54×10^{-4} cm/groove

   d. 2540 nm/groove

7. $\frac{1 \text{ in}}{10{,}000 \text{ grooves}} \cdot \frac{2.54 \text{ cm}}{\text{in}} \cdot \frac{10^7 \text{ nm}}{\text{cm}} = 2{,}540 \frac{\text{nm}}{\text{groove}}$

8. 1,000 nm/groove

9. 2,000 nm/groove

10. 1,270 nm/groove

11. 518 nm

12. 515 nm

13. 513 nm

INFORMATION ON LABORATORY ACTIVITY 26:

TEACHING NOTES:

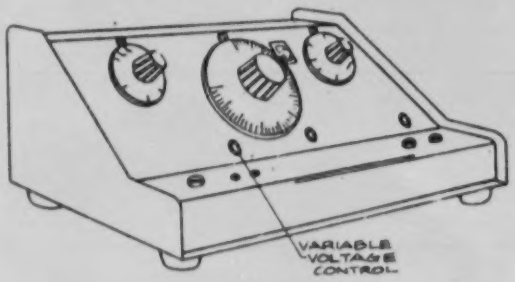
1. The purpose of this activity is to measure the wavelengths of different colors. In addition, LA-26 reinforces the idea that white light is made up of many different colors.

2. Anticipated time: one period.

3. LA-27 uses the same apparatus as LA-26. Therefore, if it is possible to leave the apparatus set up until the next lab period, much time can be saved.

4. LA-29 ("Making Lenses") should be started a few days in advance. It involves attaching a pair of watch glasses to a flat glass plate with silicone rubber cement. The cement takes 24 hours to cure. After the watch glasses are attached, they are to be filled with fluid. They almost invariably leak and have to be patched, and another 24-hour wait follows.

5. It is possible to exceed the voltage rating of the BIP-accessory lamp if the variable voltage control is rotated fully clockwise. However, unless the room is very bright it is not necessary to use maximum voltage. On the other hand, if maximum brightness is needed, caution the students to leave the lamp on for the shortest possible time.



6. If ring stands are in short supply, the light shield may be supported between two books.

7. The light bulbs supplied as BIP accessories are suitable for this activity. The light bulbs are supplied with a 24-gauge wire soldered to the tip. To connect the light bulb to the BIP, strip approximately one to two inches of insulation from the end of a BIP programming wire and wind the exposed wire around the light-bulb threads. Tape helps to keep the wire in place. The free ends of the wires may then be connected to the BIP programming panel.

8. Protractors are standard items used in the Biomedical Mathematics course. Consequently, they should be readily obtainable from the Mathematics instructor.

MATERIALS: (for 8 set-ups)

- 8 transmission diffraction gratings, 13,400 lines per inch, mounted in a 2" x 2" card
- 8 meter sticks
- 8 BIP's
- 8 light bulbs, #40, 6.3 V miniature, with 24-gauge wire attached
- tape
- 8 light shields (cardboard), approximately 15 cm x 20 cm
- 8 scissors
- 16 ring stands
- 16 ring-stand clamps
- 8 protractors

ANTICIPATED RESULTS:

We chose the five colors red, yellow, green, blue and violet. Probably your students will choose the same five.

The range of wavelengths for 6 colors of light are as follows.

Color	λ (nm)
violet	400-450
blue	450-500
green	500-570
yellow	570-590
orange	590-610
red	610-750

Colors (Left to right)	θ	sin θ	λ = d sin θ (nm)
red	21° to 19°	.36 to .33	680 to 630
yellow	18°	.31	590
green	17°	.29	550
blue	15°	.26	490
violet	13.5°	.23	440
center	0	0	
violet	12.5°	.22	420
blue	14.5°	.25	480
green	16°	.28	530
yellow	18°	.31	590
red	19.5° to 21°	.33 to .36	630 to 680

The diffraction grating stated, " 13,400 grooves/in."

$$\frac{1}{13{,}400}\ \frac{\text{in}}{\text{groove}} \cdot 2.54\ \frac{\text{cm}}{\text{in}} \cdot 10^7\ \frac{\text{nm}}{\text{cm}} \approx 1900\ \text{nm}$$

$$d \approx 1900\ \text{nm}$$

LESSON 27: (A) THE NATURE OF LIGHT

(B) WORKING WITH COLOR

RATIONALE:

This lesson extends the discussion of the fundamental nature of light and makes the point that visible light, radio waves, infrared waves, microwaves and gamma rays, etc., are all the same kind of radiation and differ only in wavelength. The point is also made in ST-27 that certain wavelengths trigger certain color perceptions, but our perception of a particular color does not require the reception of a narrow band of wavelengths. In LA-27 the nature of color perception is taken up in more detail. ST-27 concludes with a discussion of Huygens' Principle. Huygens' principle is required to explain refraction, the topic of the next lesson.

OBJECTIVES:

The student will:

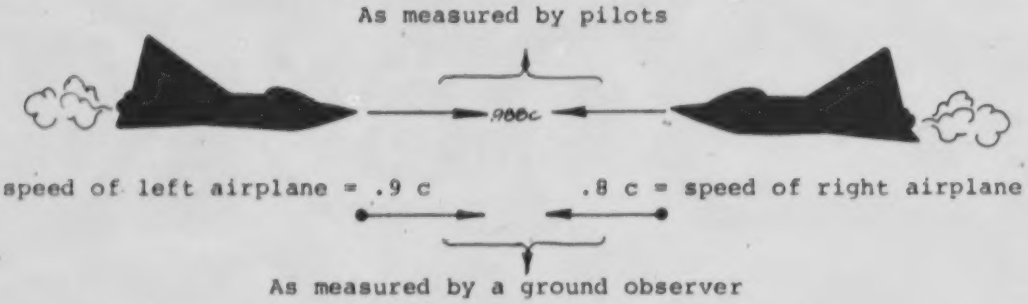
- state that visible light is a form of electromagnetic radiation.
- state at least one similarity and two differences between light waves and sound waves.
- determine the monochromatic colors passed by different colored filters.
- state that a wavelet from a previous wavefront will touch the next wavefront at only one point.
- state that the retina contains three kinds of color receptors.

SEQUENCE: ST-27; LA-27

SUGGESTIONS:

1. The history of the measurement of the speed of light, c, is an interesting chapter in the development of science. A description of the measurement techniques may be found in J.H. Rush, "The Speed of Light," Scientific American, Vol 192, No. 2 (Aug. 1955).

2. According to Einstein's Special Theory of Relaivity, the speed of light is the speed limit for the universe. In other words, nothing can travel faster than the speed of light in a vacuum. The students may be intrigued by some of the baffling implications of the Special Theory. For example, consider the situation shown in the following diagram.



Two airplanes are approaching one another very repidly. To an observer on the ground, one appears to be moving at .9 c (nine-tenths the speed of light) and the other at .8 c. However, the planes will be moving at .988 c in relation to one another.

Reasonably non-technical information on relativity may be obtained from the following sources.

M. Gardner, Relativity for the Millions, Macmillan Co., N.Y., 1962.

G. Gamow, Mr. Tompkins in Wonderland, Macmillan Co., N.Y., 1940.

B. Russell, The ABC of Relativity, Mentor Books, N.Y., 1959.

G. Gamow, Biography of Physics, Harper & Bros., N.Y., 1961 (Chapter VI).

INFORMATION ON LABORATORY ACTIVITY 27:

TEACHING NOTES:

1. The purpose of this activity is to provide an understanding of how we perceive color. The activity will also show certain properties of colored materials.

2. Anticipated time: one to two periods.

3. If you have one or more color-blind students, it would be interesting to compare their results with those of the rest of the class.

4. Note that correct results from Part I are needed to explain some of the observations made in Part II. For this reason, you may wish to have a class discussion of the results of Part I before having the students proceed with Part II.

5. In Part II, it may be desirable to follow each step with a discussion along the lines indicated under "Answers to Procedure Questions" below. In particular, Procedure Question 7 may require a level of abstraction and speculation beyond the abilities of most students. You may wish to offer an additional question as a hint: Do we need monochromatic green light to perceive green? (The answer to an analogous question about yellow light was given in the last paragraph of Section 27-2.)

6. A color wheel, if available, may be used to demonstrate that we "see" white when a combination of blue, green and orange-red color wedges are rotated rapidly.

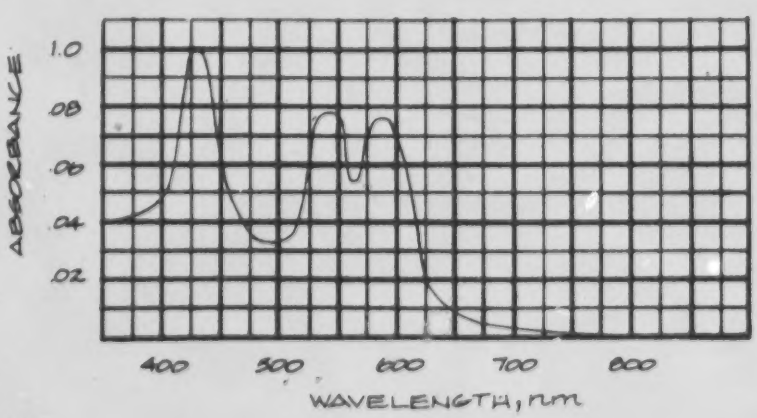
7. The BIP diode light provides a good source of narrow-band light of about 660 nm wavelength. Observing the diode light through color filters should provide results similar to those obtained at the 660-nm position with the diffraction grating set-up.

8. You may wish to discuss common color rules, such as "yellow and red make orange," etc. From a scientific standpoint, these rules are only approximately true and only under certain conditions. They are more often true with certain pigments used in painting.

9. Precise color analysis can be done with a recording spectrophotometer. This device produces a continuous curve of the absorption or reflection characteristics of a substance, typically from 400 to 800 nm. The graph below shows the absorption spectrum of oxyhemoglobin at a concentration of about 0.1% in water. Note that oxyhemoglobin freely transmits light in the orange to near infrared regions and absorbs light strongly in the violet, green and yellow regions.

MATERIALS: (for 8 set-ups)

- 4 artists' clear colored acetate sheets, 8" x 10" (1 each: red, yellow, green, blue)
- 64 microscope slides
- cellophane tape (or similar)
- 8 diffraction grating set-ups from LA-26



PREPARATION OF MATERIALS:

The acetate color filters must be used in double thickness. For ease in handling, it is recommended that the acetate be cut into 2.5 x 7.5 cm strips. Sandwich a pair of strips between two microscope slides, and tape the slides together at both ends.

ANSWERS TO PROCEDURE QUESTIONS:

1. With the red filter, red, orange and yellow wavelengths of light will appear bright; green light dim; and blue and violet almost invisible. With the yellow filter, red, orange, yellow and green light will appear bright; blue light dim; and violet almost invisible. Thus the yellow filter transmits green light much better than the red filter.

2. With the green filter, blue, green and yellow light will appear bright; red and violet dim; and orange almost invisible. The green filter transmits more blue and violet and less orange and red than the yellow filter.

3. With the blue filter, violet, blue and green light will appear bright; yellow and red light dim; and orange almost invisible. The blue filter transmits more violet and less yellow than the green filter.

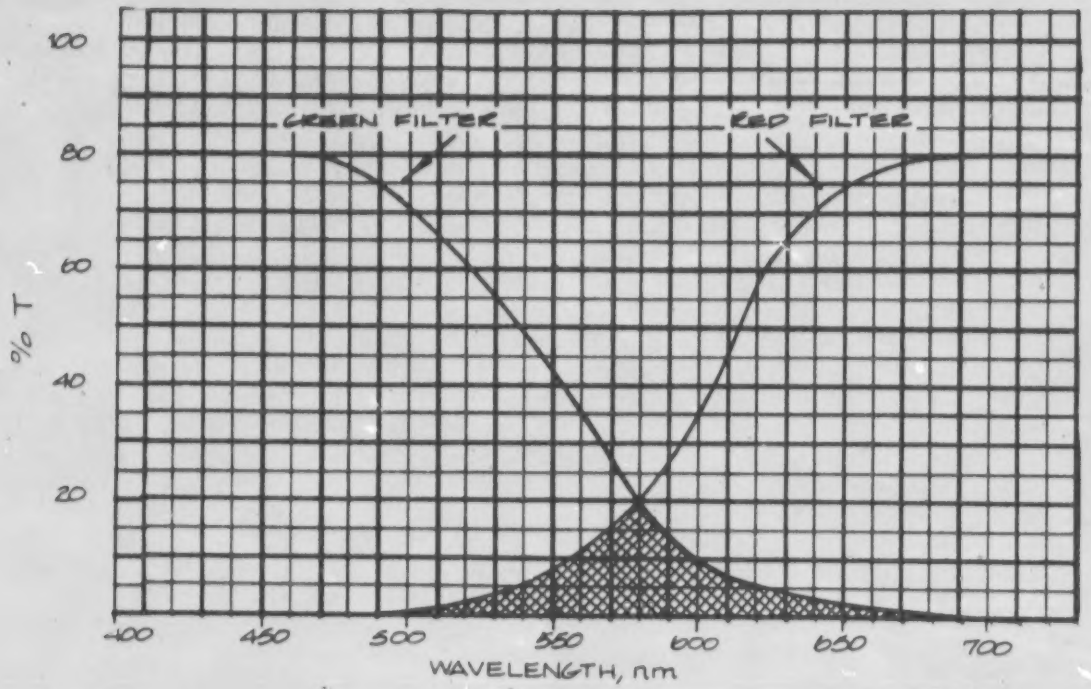
4. LA-26 demonstrated that "white" light can be broken up into a spectrum of visible wavelengths from about 400 to 700 nm. Part I, Step 2, of this activity showed that the yellow filter freely transmits light from 500 to 700 nm. The graph in the Introduction to this activity shows that G and R receptors are much more responsive than B receptors across this entire band. The brain's response to this is to perceive yellow, just as if the light were in a narrow band near 580 nm.

5. From the results of Part I it can be seen that both the blue filter and the yellow filter transmit green light freely. The other wavelengths are largely blocked by one filter or the other. The net effect is that light predominantly in the 500-550 nm region is transmitted which, as can be seen from the grapn in the Introduction to the activity, causes a perception of "green."

6. The stimulation of blue and yellow light, in addition to the green light, does not alter the brain's perception of green.

7. The observations indicate that green is perceived from a combination of yellow, green and blue light (Part II, Step 3) as well as from green light alone (Part II, Step 2). It seems reasonable to suppose that if we somehow took away green light from the yellow-green-blue combination we would still see green. This is in fact true; it has been found that we don't need light of 500-550 nm to see green. The right mixture of 450-500 and 550-600 nm light would also be perceived as green. In general, similar conditions apply to other colors (except violet and red), i.e., a mixture of a pair of monochromatic colors with wavelengths just longer and just shorter will stimulate perception of the monochromatic color in the middle.

8. It may be useful to explain color filter results in terms of superimposed light-transmission curves. The graph on the following page shows light-transmission curves (somewhat oversimplified) for the green and the red color filters. The hatched area shows the light transmitted by the combination which is predominantly in the 570-590 nm region. From the graph in the Introduction to LA-27, it may be seen that these wavelengths are in the monochromatic yellow part of the spectrum and consequently we perceive the light as yellow.



LESSON 28: REFRACTION AND THE SPEED OF LIGHT

RATIONALE:

This lesson introduces the concept of the refraction of light, in preparation for the study of lenses and human vision. To provide a mathematical understanding of refraction, the index of refraction of light for a pair of media is shown to be related to the speed of light in the two media. This mathematical description is called Snell's Law and is the single most important formula relating to refraction. In LA-28 students have the opportunity to collect data which will be used to calculate the indices of refraction of various media. The mathematical analysis of the data will be performed in the Biomedical Mathematics class.

OBJECTIVES:

The student will:

- state that light is refracted toward the line perpendicular to the boundary when it passes from a medium of lower to one of higher refractive index.
- label the following in a diagram of a refracted beam of light: incident ray, refracted ray, angle of incidence, angle of refraction.
- relate the index of refraction of a pair of media to the ratio of the speeds of light in the two media.
- state Snell's Law.
- state what the second medium is understood to be in the statement, "The index of refraction of glass is 1.5."
- collect data on angles of incidence and refraction for different pairs of media.

SEQUENCE: ST-28; LA-28

SUGGESTIONS:

1. The derivation of the speed-of-light basis of the index of refraction is optional. No subsequent material depends on the derivation itself. However, much subsequent material depends upon the result of the derivation, i.e., n = ratio of the speeds of light in the two media.

If you don't wish to present the derivation perhaps the Mathematics instructor will. Perhaps the two of you can trade some material. However, we have included the derivation in the Science Text to support the idea that not all mathematics occurs in Mathematics class.

2. If you choose to cover the derivation, Problem Set 28 may be used to reinforce the concepts involved in it. Otherwise, omit the problem set.

3. The effect of refraction can be demonstrated as follows. Wrap the outside of a 250-ml beaker in paper. Place a penny in the center and look in from the top off to one side, so that part of the bottom is visible, but not the penny. Have someone pour in water. As the water reaches the top of the beaker, the penny comes into view. This occurs because when light passes from water to air it is refracted away from the line perpendicular to the boundary.

4. A refraction model may be made as follows. An axle 8 to 10 cm long (such as a dowel or pencil) rolls on two wheels, 2.5 cm in diameter, down a slightly inclined board. A piece of cloth is used to cover part of the path by being tacked to the board. Then, when the axle is rolled at an angle to the edge of the cloth, it will change its direction upon crossing the boundary between the plain board surface and cloth surface.

5. Refraction may be used to break up white light into the colors of the spectrum. You may wish to borrow a 60° prism from the Physics Department to demonstrate this phenomenon. Another way to create a spectrum by means of refraction is to place a mirror on the bottom of a container of water and reflect a beam of light off it. The reflected beam will break up into a spectrum after it leaves the water. The reason for this phenomenon is that the index of refraction is different for different wavelengths of light. This property of refractors is called dispersion and causes many headaches for the designers of lens systems.

6. The property of refraction can cause reflection of light as well. You may wish to borrow a 90° prism from the Physics Department to demonstrate this phenomenon. It occurs when light rays from a medium with a slower speed of light strike a boundary with a medium with a faster speed of light. Consider the situation shown in Figure 1 where a beam from a flashlight is directed upward toward the surface.

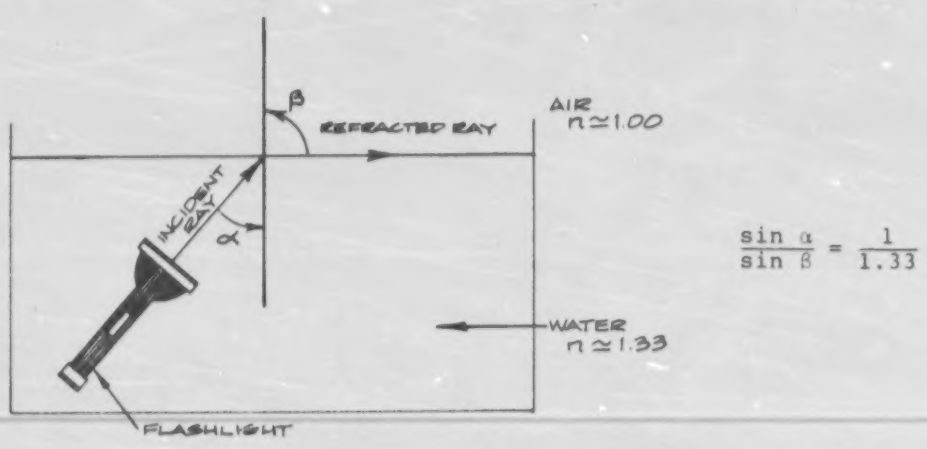


FIGURE 1: The critical angle for water.

When $\beta = 90°$ the ray from the flashlight will be refracted parallel along the surface of the water. This occurs when $\alpha \approx 49°$. For $\alpha < 49°$ the ray will enter the air. For $\alpha > 49°$ the ray will be reflected back into the water. These predictions may be easily confirmed in a swimming pool. For certain values of α you will be able to see out of the water. For $\alpha > 49°$ the surface will seem to shimmer. 49° is called the critical angle for a water-air boundary.

7. The following questions may be useful for discussion purposes.

a. In what situation would you expect the angle of incidence to equal the angle of refraction when light passes from air into water? Answer: when the ray of light is perpendicular to the boundary between the two media.)

b. When we see the sun setting, it has actually already passed below the horizon. How does this happen? (See Figure 2.)

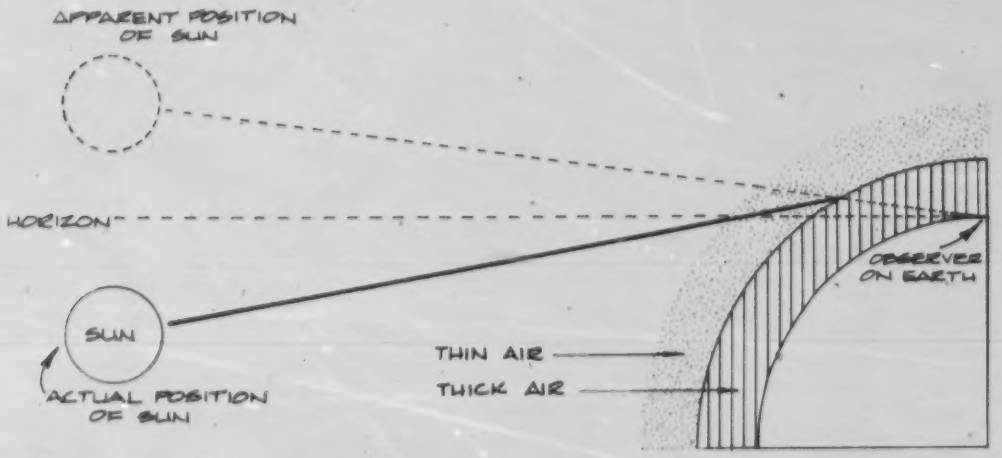


FIGURE 2: How light rays from the sun are bent to enable us to see the sun below the horizon.

c. A beam of light passes from water into glass. The angle of refraction is 30°. The speed of light in water is approximately 2.25×10^8 m/sec and in the glass it is 1.97×10^8 m/sec. What is the angle of incidence of the light beam? (Answer: water is medium 1 and glass is medium 2. Therefore,

$$n_{\text{glass/water}} = \frac{c_{\text{water}}}{c_{\text{glass}}} = \frac{2.25}{1.97} \approx 1.14$$

We know that $n_{21} = \frac{\sin \alpha}{\sin \beta}$ where α = angle of incidence and β = angle of refraction. Rearranging, we get $\sin \alpha = n_{21} \cdot (\sin \beta) = 1.14\ (.5) = .57$. Looking up this value in a table of trigonometric functions, we find that $\alpha \approx 35°$.)

KEY--PROBLEM SET 28:

1. 90°
2. θ
3. (c) $\alpha' = \alpha$
4. (c) $\frac{\text{length side opposite}}{\text{length hypotenuse}}$
5. $\sin \alpha' = \frac{\lambda_a}{h}$, $\sin \beta' = \frac{\lambda_w}{h}$
6. $\sin \alpha = \sin \alpha' = \frac{\lambda_a}{h}$
   $\sin \beta = \sin \beta' = \frac{\lambda_w}{h}$
7. (b) $\frac{\lambda_a}{\lambda_w}$
8. (b) $\lambda_a = c_a \cdot t$
9. (b) $\frac{c_a}{c_w}$

INFORMATION ON LABORATORY ACTIVITY 28:

TEACHING NOTES:

1. The purpose of this activity is to demonstrate that different media have unique indices of refraction. This will become evident upon completion of three graphs that indicate four angles of incidence and four angles of refraction each for air/water, air/glycerin and air/air.

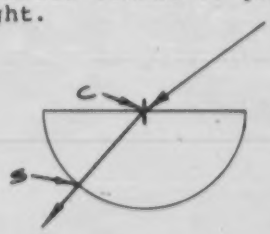
2. Anticipated time: one period.

3. The plastic semicircular containers might be borrowed from the Physics Department if they teach the PSSC course. They are also available from Eduquip-Macalaster Corporation. (Catalogs may list them as "boxes" or "tanks.")

4. The graphs should be collected at the end of the period and given to the Mathematics instructor. The mathematical analysis of the data will be done in Mathematics floating sequence X.

5. If necessary, the plastic containers can be made from plastic Petri dishes, by students, as follows. Cut the bottom of the dish exactly in half. (Cutting is done with a small knife or scalpel that has been heated directly in a gas flame. The knife works by melting the plastic, so it need not be a sharp one.) From the Petri dish lid, cut out a rectangle large enough to act as the flat side for the semicircular dish. (See LA-28, Figure 2.) Then use silicone rubber cement to glue the flat piece on with a watertight seal. Allow to dry overnight.

6. The semicular shape is fundamental to the design of the activity (Figure 3). If a ray strikes the center of curvature (c) of the semicircle, it will be bent once at the flat surface, exit the box at a right angle to the curved surface and not be bent again. Since the ray is bent only once, it is much easier to analyze the pattern of the results.



7. 90 to 100 ml glycerin are needed per container. To reduce the amount of glycerin needed, two to four semicircular plastic containers can be filled and the lids labeled.

8. In step 9 the students are asked to remove the boxes after each pin placement, then draw lines and label angles. If this step is not done as directed, the probability increases of confusing which α's and β's are paired.

9. You may wish to explain to the class that "glycerin" is merely the common name for glycerol, a substance that received considerable attention in the Nutrition Unit.

10. You may wish to have the students return the glycerin to a stock bottle for future use.

MATERIALS: (for 15 set-ups)

- 15 semicircular transparent containers
- 60 paper clips
- 30 straight pins
- 45 sheets graph paper, 1/2-cm
- 15 pieces soft cardboard, 8 1/2" x 11"
- 1500 ml glycerin
- 15 beakers, 150-ml
- 15 mm rulers
- 15 glass-marking pencils

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ANTICIPATED RESULTS:

The drawing at right shows an example of the finished graph when water is used as a medium.

ANSWERS TO DISCUSSION QUESTIONS:

1. Tests in our laboratory showed that the greatest differences between α and β occurred with glycerin. Glycerin has a higher index of refraction than water.

2. Glycerin.

3. These substances reduce the speed of light passing through them. How this causes bending is explained in ST-28.

LESSON 29: LENSES

RATIONALE:

This lesson extends the concept of the refraction of light, presented in the last lesson, to explain how convex lenses function. Since the eye is essentially a convex lens system, this material is basic to an understanding of how an image is formed on the retina. The mathematical relationship between image distance (d_i), object distance (d_o) and focal length (f) is also presented. This relationship is necessary to explain why the process of accommodation is required in vision. In LA-30 students will make measurements that will show that the closer an object is to a lens of fixed focal length, the farther away an image is formed. All the material in this lesson is fundamental to an understanding of the causes of refractive errors such as myopia, hyperopia and astigmatism. LA-29 entails the preparation of the lenses and solutions that will be used in LA-30.

OBJECTIVES:

The student will:

- explain, when provided with an appropriate diagram, the ability of a convex lens to converge rays of parallel light that pass through it.
- state how the object distance determines whether the image produced by a convex lens is real or virtual, and recognize diagrams that show how each of these types of images are formed.
- define the terms in the formula $\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$, and use the formula to solve for the third variable when two of the variables are given.
- prepare lenses and sucrose solutions, using the instructions given in LA-29.

SEQUENCE: ST-29; LA-29

SUGGESTIONS:

1. If a concave lens is available, you may use it to show that it produces smaller images. Concave lenses are used in the construction of lens systems to correct for chromatic aberration caused by dispersion (Figure 1). All refractors disperse light but to different degrees.

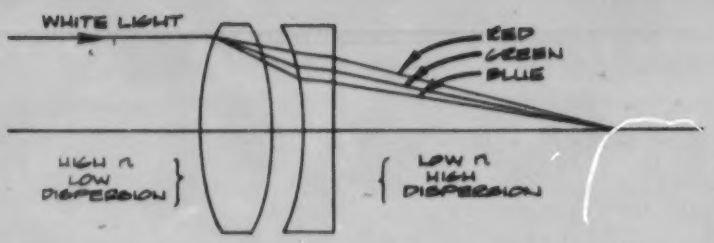


FIGURE 1: Chromatic aberration can be corrected by combining glasses with different dispersions. In this simple two-element lens the first element is made from low-dispersion glass. The second element, of opposing power but weaker, is made from high-dispersion glass. Dispersion is canceled out but focusing power remains.

3. An excellent discussion of the problems of lens design may be found in W.H. Price, "The Photographic Lens," Scientific American, Vol. 235, No. 2 (Aug. 1976). This article will instill in the reader an appreciation for the combination of high performance and simplicity in the human eye.

4. You may wish to discuss how magnification is related to image distance, object distance and focal length. In Figure 2 it is known that the object (O) and focused image (I) are related as shown. Both light rays $\overline{be}$ and $\overline{ad}$ pass through the center (c) of the lens. For the similar triangles abc and dec we may write

$$\frac{\text{length de}}{\text{length ab}} = \frac{d_i}{d_o}$$

The ratio on the left is the magnification ratio and is equal to the ratio of d_i to d_o.

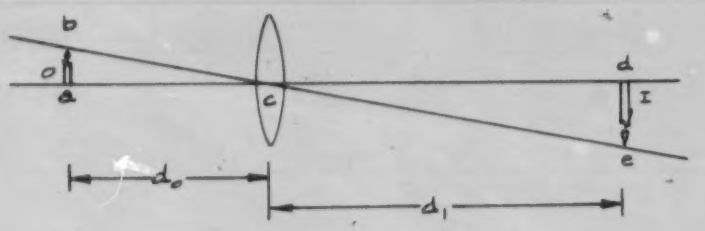


FIGURE 2: How d_o and d_i are related to magnification.

INFORMATION ON LABORATORY ACTIVITY 29:

TEACHING NOTES:

1. The purpose of this activity is to prepare materials needed for Laboratory Activity 30.

2. Anticipated time: one period.

3. After the lenses are made they are checked for leaks (Part I, Step 9). If a leak is present, it takes another day to check the repair. A second repair and day's wait may be necessary, too. Thus it is appropriate to begin Part I of LA-29 well in advance of Part II, as indicated in earlier lessons.

4. The indicated sizes of the glass plates are close to the minimum. Larger ones may be used.

5. Heat will hasten the process of dissolving the sucrose for the 50% solution.

6. To conserve sucrose, each team could prepare only one of the sucrose solutions. Then, in LA-30, each team could prepare and test its lenses using only that solution, and trade lenses with another team. In this case, lenses should be labeled (at the edge) with the concentration of the solution they contain.

7. As an alternative, particularly if time is running short, you may wish to mix classroom quantities of the sucrose solutions yourself as follows.

3.0 kg of 25% sucrose solution: .75 kg sucrose + 2.25 liters hot tap water

3.0 kg of 50% sucrose solution: 1.5 kg sucrose + 1.5 liters hot tap water

8. If the silicone rubber sealant is smeared on the watch glasses, it may be cleaned off with either naphtha or lighter fluid. These fluids will remove the sealant in either its wet or dry states.

MATERIALS: (for 15 set-ups)

- 30 watch glasses, 100-mm diameter
- 30 watch glasses, 50-mm diameter
- 15 glass plates, 100 x 110 mm (or larger)
- 15 glass plates, 50 x 60 mm (or larger)
- 2.25 kg sucrose (table sugar)
- 30 beakers, 250-ml
- 30 Erlenmeyer flasks, 250-ml
- 15 graduated cylinders, 100-ml
- 15 balances
- 15 stirring rods
- 30 cork stoppers, #14 (or rubber, #6)
- 15 glass-marking pencils
- 4 or 5 tubes air-curing silicone rubber cement

LESSON 30: (A) THE LENS MAKER'S FORMULA

(B) DETERMINING THE FOCAL LENGTH OF LENSES

RATIONALE:

The lens maker's formula relates the radii of curvature of the two surfaces of a lens and the difference between the refractive indices of the lens and the surrounding medium to the focal length of the lens. Both the refractive index and the radius of curvature have important influences on the focusing characteristics of the eye. For example, most light-bending in the eye occurs at the air-cornea boundary because the difference between refractive indices is greatest there. The effect of the radii of curvature of the lens is important in the process of accommodation. The eye decreases the radii of curvature of the lens in order to focus closer objects on the retina. In addition, an eye practitioner must be familiar with the lens maker's formula in order to either prescribe or make corrective lenses. This formula is further developed in LA-30, during which students experiment with the effects of index of refraction and radius of curvature on the focal length of lenses. The mathematical analysis of their measurements will be made in the Mathematics class.

OBJECTIVES:

The student will:

- state two factors that affect the focal length of a lens, i.e., (1) radius of curvature and (2) the difference between the refractive indices of the lens and the surrounding medium.
- use the lens maker's formula to solve for focal length, when the indices of refraction and radii of curvature are given.
- define radius of curvature.
- determine the radius of curvature of a watch glass.
- measure and calculate the focal lengths of lenses with different radii of curvature and different refractive indices.

SEQUENCE: ST-30; LA-30

SUGGESTIONS:

1. If available, use a light-and-lens demonstration kit to show a convex lens converging rays and a concave lens diverging rays.

2. If an assortment of lenses is available, have the students use them to compare focal lengths.

3. Construct a model of a compound microscope using two lenses and a piece of paper with writing on it. Hang the paper vertically on a wall or ring stand. Mount the more powerful of the two lenses in front of the paper. This lens represents the objective of the microscope. View the real, inverted image formed. Now hold the weaker lens (eyepiece) between yourself and the objective lens. The image will be inverted but larger. The lenses made in the laboratory can be used. Filling them with water will suffice. Place the smaller one in front of the paper at a distance where the image is inverted and larger. Then hold the larger lens and find the position where the image is still inverted but larger yet.

INFORMATION ON LABORATORY ACTIVITY 30:

TEACHING NOTES:

1. The purpose of this activity is to collect data from student-constructed lenses. The data will be used in Mathematics class to determine focal lengths.

2. Anticipated time: one period.

3. A data sheet is provided at the end of this lesson. It should be copied and distributed--one copy per student. Students should record their data on these sheets. The data sheets should be collected at the end of the activity and given to the Mathematics instructor.

In Mathematics class, the data sheets will be returned to the students, who will then use them to calculate focal lengths. No anticipated results are given here for this activity, since the results will be determined in the Mathematics class. The reason for distributing copies of the data sheet is to assure a uniform format for data recording. This will be important in the Mathematics class.

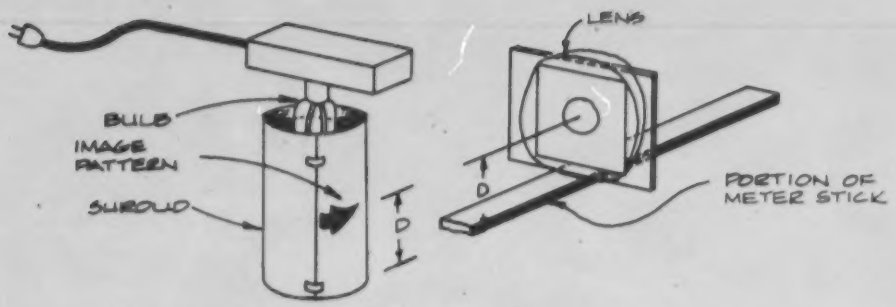
4. The data obtained in this activity will be analyzed in Mathematics Lessons Y1 and Y2. You may wish to read those two lessons in order to see how the measurements taken in LA-30 are related to focal length.

5. Be sure the lenses have been checked for leaks (LA-29, Part I, Step 9) before starting this activity. If there is lens leakage, the leaking spot should be wiped dry of liquid, a dab of silicone rubber applied and another day should be allowed for curing.

6. A syringe with rubber tubing instead of squeeze bottles, may be useful to fill lenses with solution.

7. If you wish to provide an image pattern, such as an arrow, the pattern can be cut through a 5" x 8" index card and the card rolled into a cylinder and shrouded around the light source as shown on the following page. The pattern should be cut at the same height as the height of the center of the lens above the tabletop. Make sure there is air space between the card and the bulb to avoid burning the card.

8. One procedure for focusing the image is to establish the points at which the image is obviously going out of focus by moving the screen toward the lens then away from the lens. Between these two points it is almost necessary to guess when the image is in focus because of the limited degree of resolution provided by the source and lens. It may be helpful to use only one part of the image in focusing.



MATERIALS: (for 15 set-ups)

30 lenses and sucrose solutions (from LA-29)
15 meter sticks
15 mm rulers
45 index cards (4" x 6" or 5" x 8")
masking tape
15 pipets, 10-ml
15 wash bottles
15 light bulbs, 100-watt, clear
15 bulb sockets with cord and plug
15 ring stands with clamps
8 to 15 scissors

ANSWER TO DISCUSSION QUESTION:

1. The watch glasses are not of uniform thickness. Look at objects through an empty watch glass; they will appear distorted. The irregular surface refracts light in an irregular way. When the watch glass lenses are filled with fluid, the irregular refraction causes uncertainty in the focus.

Another potential cause of uncertainty is the alignment of the watch glasses. If a line drawn through the center of both watch glasses is not perpendicular to the glass plate, then the geometry of the lens will not match the geometry of ordinary glass lenses. Since the formulas were derived based on this geometry, deviations from it will change observed results.

NAME: _____

SCIENCE DATA SHEET 30

Watch glass depth: d = _____ cm

Watch glass width: w = _____ cm

$r = \frac{w}{2}$ = _____ cm

R = _____ cm

Lab partner #1 _____

Lab partner #2 _____

	0% Sucrose			25% Sucrose			50% Sucrose		
Screen position (cm)									
d_o: object distance (cm)									
d_i: image distance (cm)									
Experimental focal length (cm)	f_1	f_2	f_3	f_1	f_2	f_3	f_1	f_2	f_3
Mean focal length, $\bar{f}$ (cm)									
Deviations from mean focal length: $f_i - \bar{f}$ (cm)									
$(f_i - \bar{f})^2$ (cm^2)									
Standard Deviation, s (cm)									
Theoretical focal length, f_θ (cm)									

LESSON 31: (A) ANATOMY OF THE EYE

(B) FOCUSING IMAGES ON THE RETINA

(C) DISSECTION OF AN ANIMAL EYE

RATIONALE:

Lesson 31 covers the anatomy of the eye and the functions of its parts. In particular, the information on convex lenses that was presented in the preceding two lessons is used here to explain the process by which the lens of the eye focuses images onto the retina. This information forms the groundwork for understanding the cause and treatment of myopia(nearsightedness) and hyperopia(farsightedness), to be researched and reported on by students in the next two lessons.

OBJECTIVES:

The student will:

- label at least eight of the following parts of the eye on an appropriate diagram: sclera, choroid, aqueous humor, vitreous humor, cornea, iris, lens, ciliary muscles, suspensory ligament, retina.
- use the formula $\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$ to explain why the closer an object is to the eye, the farther its image is from the lens.
- explain the role of the lens in accommodation.
- state how the diameter of the pupil varies with light intensity.
- state two effects of a reduction in pupil size.
- dissect an eyeball and locate at least eight of the following structures in an eyeball: optic nerve, retina, cornea, sclera, aqueous humor, iris, pupil, lens, vitreous humor, ciliary body.

SEQUENCE: ST-31; LA-31

SUGGESTIONS:

1. Figure 1 may be useful to supplement the treatment of accommodation in the Student Text. It shows that the smaller the radii of curvature of a convex lens, the more light rays converge. As a result, the smaller the radii of curvature, the closer the focused image will be to the retina.

Lens is not accommodating. The image is out of focus at the retina.

Lens is accommodating (its radii of curvature have decreased). The image is in focus at the retina.

FIGURE 1: Accommodation and focusing.

2. Students may do the following to demonstrate accommodation. Look across the room at an object. Close one eye. Hold one finger up about a foot in front of the open eye. Look at the distant object. The finger becomes blurred. Then look at the finger so that it is clearly focused. The distant object becomes blurred.

The explanation is that the shape of the lens changes for near and far vision (accommodation). It cannot focus near and far objects onto the retina simultaneously.

3. ST-31 states that the closer the object is to the eye's lens, the farther the image is from the lens, and that this calls for accommodation. Another way to explain why accommodation is necessary is as follows. Light rays arriving at the eye from objects 20 feet away or farther are more nearly parallel than light rays from near objects (Figure 2). Rays from near objects are more divergent when they arrive at the eye. The divergent rays come to a focus farther from the lens than do the parallel rays.

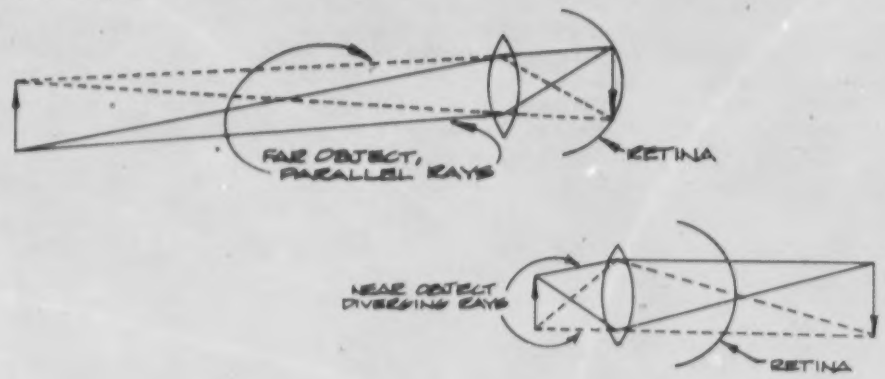


FIGURE 2: Light rays from far and near objects.

In accommodation, the diverging rays are focused onto the retina by being bent by the lens more (Figure 2 above).

INFORMATION ON LABORATORY ACTIVITY 31:

TEACHING NOTES:

1. The purpose of this activity is to reinforce the study of the structure of an eye.

2. Anticipated time: one period.

3. Preserved sheep eyes (Carolina P2130) are available at $3.75 per 12 or $.40 each. They are also available from Ward's (61 W7150) for $3.00 for 10. Fresh eyes may be obtained from slaughterhouses for slightly less.

4. The sheep's eye is somewhat different in appearance from the human eye, and this may cause some confusion. In the sheep's eye, one sees what appears to be a large blue iris, and the pupil is usually not visible. The outside edge of the cornea coincides with the border of the blue area. Once the cornea is removed, the pupil and the lens are visible.

5. Students may infer from dissection of a preserved eye that the lens is too hard to be pulled or pushed into different shapes as required by the process of accommodation. The lenses that are present in the preserved eyes are much more rigid than those of the living animal.

6. If the students place their sheeps' eyes under a lamp and try to look inside, they will not be able to see much because the light source will be in their way. By placing the light off to the side and using a hand mirror to reflect light into the eye, more information may be obtained. (Reflectors worn on the forehead by physicians who specialize in the ear, nose and throat are used for this reason, too.)

7. If the students have trouble locating the retina, it may be because a retina has come loose during the dissection. A detached retina can sometimes be found by locating its attachment at the point where the optic nerve enters the eye, or by submerging the eye in a bowl of water. The retina will float free and straighten out.

8. A good demonstration of internal eye structure can be prepared by freezing several eyes and cutting through each one in a different plane. (Use a fine saw and cut while the eyes are still frozen.) Mount the eyes in styrofoam blocks so that the cut surface of the eye is exposed.

MATERIALS: (for 15 set-ups)

- 15 sheep eyes (more if you make frozen mounts)
- 15 Petri dishes (or dissecting pans)
- 15 razor blades, single-edge
- 15 dissecting scissors or scissors with sharp points
- 15 forceps
- 15 hand lenses
- 15 hand mirrors
- light source

ANSWERS TO PROCEDURE QUESTIONS:

1. Their function is to move the eyeball in the eye socket when the animal looks in different directions.

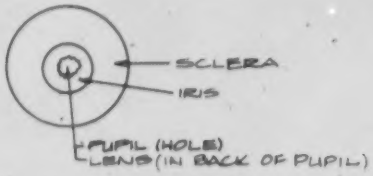
2. The optic nerve enters at the optic disk.

3,4. The answers should be "Yes."

5. The cornea is more nearly transparent than the sclera.

6. Aqueous humor. It helps maintain the shape of the cornea.

7.



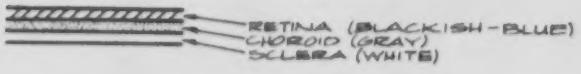
8. The lens in a preserved specimen is opaque or cloudy, and has the consistency of soft rubber.

9. The preserved lens is translucent, whitish in color, very firm, smaller than a dime, round in shape, smooth.

10. Students may be able to see a bluish-colored membrane (the retina) with what looks like small blood vessels in it.

11. The answer should be "Yes."

12. The layers are shown below.



LESSON 32: THE RETINA IN VISION AND DIAGNOSIS OF DISEASE

RATIONALE:

In ST-31 the anatomy and physiology of the eye were discussed, as well as the way in which light is refracted when it passes through the various structures of the eye. This lesson is concerned with what happens when light strikes the retina and how the visual image formed on the retina is transmitted to the brain. In this context, the receptors of the retina are discussed as well as how the neural impulses that they initiate are passed along the optic nerves to the visual centers of the brain. The neural pathways of the optic nerves are described to explain how visual-field testing may be of use in the diagnosis of brain tumors.

Although the bulk of this lesson is concerned with the retina and its function in vision, this structure is also studied in the diagnosis and evaluation of systemic diseases. Some of the data that can be obtained from an examination of the retina are of value in diagnosis of diabetes and hypertension.

An activity has also been included in which the students do library research on various disorders of the eye and then make oral reports to the class. (Notes on this activity are attached.)

OBJECTIVES:

The student will:

- state how the rod and cone receptors differ in structure, function and distribution on the retina.
- explain why vitamin A is necessary for the proper functioning of the rods.
- define fovea centralis and state why visual acuity is greatest in this area of the retina.
- define dark adaptation and color blindness.
- state how a knowledge of the neural pathways followed by the optic nerves can be of use in diagnosing a brain tumor.
- explain how the retina is useful as a diagnostic indicator in diseases such as diabetes and hypertension.
- use library materials to determine the nature, symptoms and treatment of a specific visual dysfunction.

SEQUENCE: ST-32; Activity 32

SUGGESTIONS:

1. In ST-32 when ophthalmoscopic examination of the retina is discussed the students are told that they will have an opportunity to observe the flow of red blood cells in their own retinas. To set up this demonstration the following equipment is needed:

soft white light bulb (60-100 watts)

Wratten gelatin filter No. 47B (Eastman Kodak, Cat 1494376, $2.10)

To observe the flow of red blood cells, the room should be as dark as possible, except for the white bulb you are using for the demonstration. The students then take turns positioning themselves at a distance of 60 to 90 cm from the light source and looking at the light through the filter. After a few seconds, they will begin to see many "dots" moving rapidly in all different directions. These "dots" are actually the red blood cells flowing through the retina. It may even be possible to distinguish one general area where there is no movement; this would correspond to the fovea centralis on the retina.

An alternate way to set up this demonstration is to use the quadrant of light cast on a white wall by a slide projector as the "light source." Also, a 1-cm thick glass cell containing a solution of copper sulfate dissolved in excess of ammonium hydroxide may be substituted for the Kodak filter. The solution will be a deep blue color. (The exact concentration of reagents is not important.) The cell can be constructed by cementing square glass slides together with silicone cement to form a "box." If this alternative is used, it is important that the opposite sides of the cell be parallel to prevent optical distortion. Also, students should be warned that the blue solution stains skin and clothing.

It is not fully understood how this demonstration works. It is thought to be the result of a combination of effects such as:

a. the red blood cells cast shadows on the retina that provide the necessary stimulation.

b. that what is actually observed is the after-images of the moving cells.

c. the cells act as lenses, concentrating the incident light and producing luminous images of themselves.

d. the red blood cells are self-luminous due to reflection of light inside them.

e. the cells absorb light at wavelengths of 415, 542 and 577 nm with the maximum absorption occurring in the blue-violet range.

2. In ST-32 only one example was given of how mapping a person's visual fields can yield information of diagnostic value in locating a brain tumor. There are many other visual-field defects that are of diagnostic value in medicine, as indicated in Lessons 5, 6 and 8. If any of the students are interested in researching this topic further, more extensive coverage can be found in the following reference:

Harrison's Principles of Internal Medicine, M.M. Wintrobe, G.W. Thorn, R.D. Adams, et al., (Eds.), 6th Ed. McGraw-Hill Book Co., New York, 1970.

3. There are a great many dysfunctions of the eye that may be of interest to the students. Because the amount of material would be too extensive to include in the Student Text, we have suggested that the students do a research activity in which they are responsible for looking up information on a specific dysfunction and making an oral report to the class. Suggestions on how to organize this activity follow under the heading "Information on Activity 32."

4. Students may be interested in the phenomenon of negative after-images. This can be demonstrated by having them focus in strong light (e.g., sunlight) on a geometrical figure that is red on a white background. They should focus on the figure for at least two minutes. Then have them switch their focus to a blank piece of white paper. They will see an after-image of the same figure, but the color will be green. The reason for this phenomenon is that staring at the red figure for a period of time causes the receptors for the wavelengths of light that correspond to the color red to become fatigued. When they look at a piece of white paper, the red receptors react minimally due to fatigue while the response from the other receptors is relatively stronger. This combination of responses is interpreted by our brain as "green."

5. Our discussion of visual perception has been limited to an objective examination of how the eye functions. However, there are a great many subjective factors which influence how we see contours, shades of dark and light and color. Scientific American has an excellent publication that discusses some of these areas of visual perception. It is entitled "Image, Object and Illusion" and was published in 1971. If your school library has this item you might want to have it available in the classroom during the time when the eye is being discussed. (Offprints of the separate articles contained in the publication are also available for a small charge. To obtain them write to W.H. Freeman and Company, 600 Market Street, San Francisco, California, 94104.)

INFORMATION ON ACTIVITY 32:

TEACHING NOTES:

1. Instead of including detailed information on visual dysfunctions in the Student Text as is our general practice, it is included here to provide an opportunity for student library research. You may wish to assign a specific dysfunction from the list that follows to each student. Or you may wish to assign topics not included in the list. Once the students have gathered the information, time should be provided for discussion. We have scheduled this for the activity period of Lesson 33.

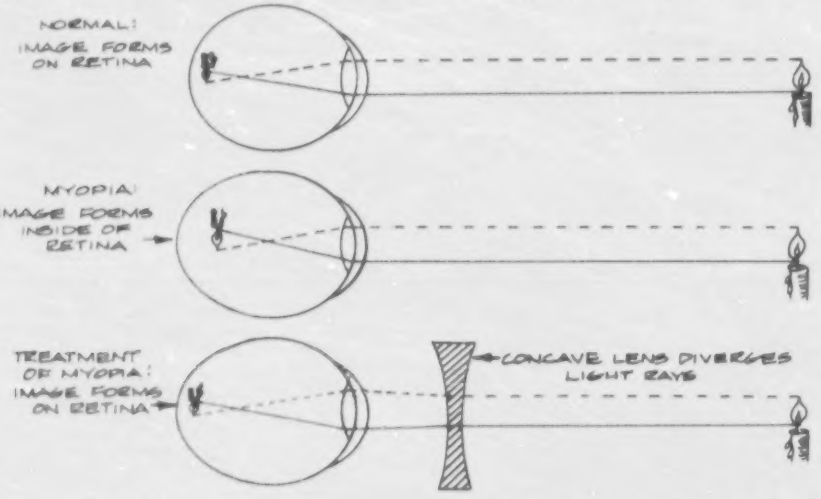
2. Anticipated time: two periods, one for research and one for discussion.

3. Some method of preserving and sharing the information collected on visual dysfunctions should be set up. For example you may wish to have students give oral reports on their assigned topics and have other students take notes. Alternatively you may wish to copy and distribute the Information on Visual Dysfunctions below.

INFORMATION ON VISUAL DYSFUNCTIONS:

Myopia: In the myopic eye, parallel rays from a distant object converge before reaching the retina. The maximum object distance at which rays converge on the retina in the myopic eye is called the myopic far point. This point will vary. The more myopic the individual, the closer that point will be to the lens. It may be 15 to 18 cm. Every object beyond that point is blurred and diffuse because the image focuses at some point in the vitreous humor instead of on the retina.

This condition is usually caused by a disproportionate lengthening of the eye and therefore of the visual axis. Myopia is not accompanied by a corresponding decrease in the refractiveness of the lens. The solution to this problem is to provide concave lenses. These diverge the light rays slightly so that when they pass through the eye, they are focused farther back (i.e., on the retina).

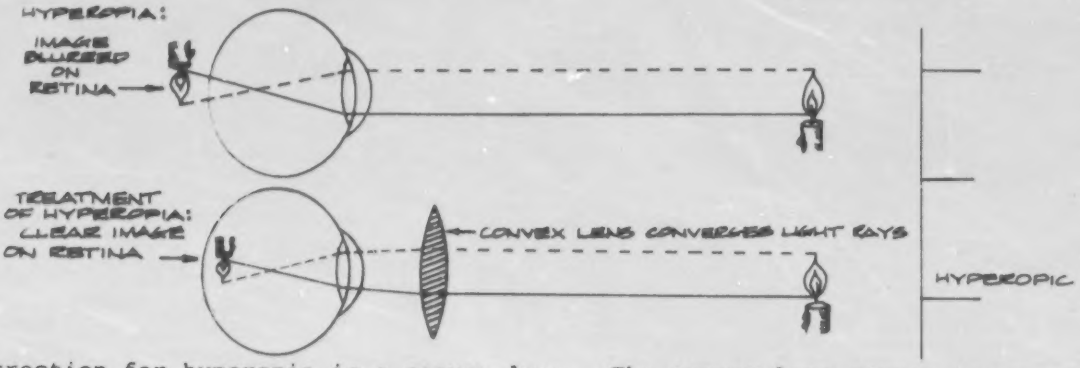


The strength of the corrective lens needed is determined by the degree of divergence necessary to focus light from distant objects on the retina.

The corrective lenses worn by people with myopia are concave on one side and convex on the other. Nevertheless they act as concave lenses because their center is thinner than their periphery.

Hyperopia: In this case parallel rays come to a focus behind the retina, i.e., they are not sufficiently refracted when passing through the eye. The condition may be caused by a shortening of the eye length (visual axis) without a corresponding increase

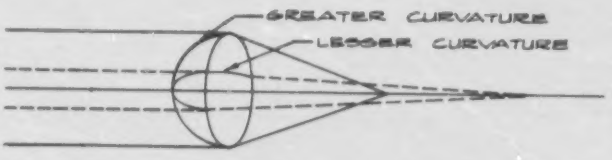
in the refractiveness of the lens. Therefore, a hyperopic eye must accommodate to see even a far object, i.e., must use the ciliary muscles to make the lens more convex so that the image falls on the retina. (This can be likened to what the normal eye must do to see close up.) In order to see at close range the hyperopic eye must undergo much strain, since it must accommodate even more than the normal eye. For this reason the close work, such as reading, that a hyperopic person without glasses can do is limited.



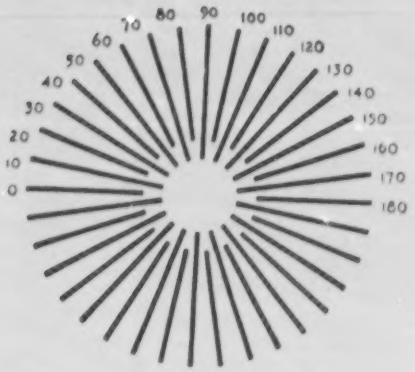
The correction for hyperopia is a convex lens. The convex lens serves to converge the light somewhat before it enters the eye so that only a normal degree of accommodation is necessary to make the image fall on the retina.

Presbyopia: This is a decline in the ability of the eye to accommodate, usually associated with aging. Thus the closest point at which one can see well gets farther and farther away until close work is not possible without correction by convex lenses. Most people with normal vision develop presbyopia and need reading glasses near the age of 45. People who are myopic are not affected as much because their "near point" is so close that as it recedes it tends toward the normal range instead of away from it. People with hyperopia often find it almost impossible to do close work. Their near point was far away to begin with, and with age it recedes even farther, making the accommodation necessary so great as to be impossible in some cases.

Astigmatism: In an ideal eye the refractive surfaces of the lens and cornea are uniformly spherical. In some eyes, however, the corneal surface does not have the same curvature for different cross sections. An example is given in the following diagram, where the cornea is more curved along its vertical cross section than along its horizontal cross section or "meridian." In this case, the vertical meridian is called the meridian of greater curvature. It has a smaller radius of curvature. The horizontal is called the meridian of lesser curvature and has a larger radius of curvature. Since the radius of curvature is less for the vertical component, it would be expected that light rays passing through on this meridian would converge before those passing through on the meridian of lesser curvature. (Remember the less the radius of curvature of a convex lens, the more the refraction and the shorter the distance to convergence of the rays.) Thus, for example, if one were to look at a cross in the case mentioned, it would not be possible to focus both the horizontal and vertical bars simultaneously. At that point (distance) where the horizontal rays are focused, the vertical ones will not be and vice versa. Therefore someone with astigmatism can focus only on one bar at a time, but not on both at once. He can focus on any number of things within his field of vision at the same time as long as they are either in a horizontal or vertical position, but no mixture is possible. Thus in the figure opposite he would see clearly either the vertical arrow or the horizontal arrow, and the other would appear fuzzy.



The diagram to the right is often used to test for astigmatism.



By observing which lines are darker and which fuzzier, one can pinpoint the axes of least and greatest curvature. The correction for astigmatism is a cylindrical lens or a combination of cylindrical and spherical lenses placed so as to equalize the refraction meridians of the greatest and least curvature.

Strabismus: This is a condition in which the visual images formed in the right and left eye do not coincide due to a failure on the part of the eye muscles to align both eyes correctly when looking at an object. This is commonly caused by a weak muscle on one side of one eye resulting in one of the eyes being turned slightly outward. Being cross-eyed is also a form of strabismus, although not a very common one. The correction of strabismus involves exercising the weak muscle to strenghten it or, in some more severe cases, surgery. If surgery is performed the muscle opposing the weak one is usually shortened, pulling the eye back into proper alignment.

Cataracts: Cataracts are an especially common eye abnormality that occur in older people. A cataract is a cloudy or opaque area in the lens. Cataracts arise from a process of protein coagulation and deposits of calcium in the lens. The condition, if severe enough, may require surgical removal of the lens. A powerful convex lens in front of the eye is substituted for the actual lens. Of course, accommodation over a variety of object distances is not possible.

Glaucoma: Glaucoma is a disease of the eye in which the intraocular pressure (the pressure maintained by the aqueous and vitreous humors to keep the eye distended) becomes abnormally high (ocular hypertension). This can be caused by increased secretion of fluids or by impaired outlet of the fluids. It is most often caused by the latter. As the pressure rises, the retinal artery is compressed, thus reducing the nutrition to the retina. This often results in permanent atrophy of the retina and optic nerve, with consequent blindness.

Glaucoma is one of the most common causes of blindness. Very high pressures, lasting only a few days, can at times cause total and permanent blindness. In cases with only mildly elevated pressure, the blindness may develop progressively over a period of many years. An instrument known as a tonometer is used to measure intraocular pressure. Basically, this instrument consists of a pressure gauge and a rod of metal. The cornea is first anesthetized with eye drops. Then the instrument is placed upon the cornea of the eye so that the rod pushes down on the cornea. The gauge measures the amount of indentation resulting from the weight of the plunger. If glaucoma is present, the cornea will be under increased pressure and the plunger will indent less. Corrective measures (drugs, surgery) are focused on reducing the intraocular pressure. The tonometer is calibrated in mm Hg. Normal intraocular pressure is from 10 to 20 mm Hg. Results from 20 to 25 mm Hg suggest glaucoma and measurements over 25 almost certainly indicate glaucoma.

Amblyopia due to disuse: Very often an individual who has strabismus may learn to suppress the image from one eye thus eliminating double vision. Visual acuity may decrease in the "unused" eye, so that the eye does not see clearly even when the other eye is covered. This condition is called amblyopia due to disuse or "lazy eye." The usual method of treatment is to place a patch over the normal eye and force the use of the amblyopic eye. Treatment is more rapid and successful with younger children.

Optic atrophy: Although, strictly speaking, "optic" atrophy refers to the wasting away of any part of the eye, the term is commonly used to designate atrophy of the optic nerve. The causes of such atrophy are varied; it may be hereditary. It may also be the result of an eye disease such as glaucoma, a neurological disease

such as multiple sclerosis or a toxic material such as methyl alcohol. Blurred vision and central defects of the visual field are the earliest signs. Upon ophthalmologic examination, the optic disk (where the optic nerve inserts into the retina) appears pale and clearly outlined. Treatment depends upon what disorder is causing the atrophy. In the case of glaucoma, treatment would be to relieve the hypertension in the vitreous humor, thus restoring proper circulation.

Detached retina: The retina is rather loosely attached to the pigmented layer underneath. The retina can become detached from the layer underneath and float freely in the vitreous humor as a result of several conditions, the commonest being severe trauma and diabetes. Detached retina is not uncommon in boxers. Prompt medical treatment with a laser beam usually allows the retina to be "tacked" onto the pigmented epithelium. A period of weeks at rest is necessary for a secure union to take place.

Diabetic retinopathy: Loss of vision due to diabetes is the third most frequent cause of blindness, after cataracts and glaucoma. Diabetes may result in changes in the capillaries. One change causes microhemorrhages to occur which can eventually damage vision. Coagulation by laser beam of the retinal protein around the affected area has been somewhat successful in preventing further vision loss. In some cases of diabetes, new capillaries appear where they aren't needed; this too causes impairment of vision by affecting the retina.

INFORMATION ON EYE PROBLEMS NOT NECESSARILY ASSOCIATED WITH VISION DISTURBANCE:

Sty

This is a pimple-like infection of one of the glands of the eyelid. It is commonly caused by bacteria, usually streptococcus. Treatment may utilize heat and/or antibiotics.

Pink eye

This usually refers to a highly contagious acute conjunctivitis of viral or bacterial origin. (Conjunctivitis is an inflammation of the conjunctiva, and the conjunctiva is the mucous membrane covering the anterior part of the eyeball.) A purulent mucous discharge is often present. While most forms of pink eye are not dangerous, gonococcal conjunctivitis can cause damage to the cornea.

Trachoma

This is a contagious chronic viral infection of the cornea and conjunctiva that currently affects about one/eighth of the world's population. Severe infection leads to scarring of the cornea and ultimately to blindness. Early cases of trachoma can be cured by chemotherapy but reinfection is common in countries where sanitation is poor.

Chemical conjunctivitis

Also called smog conjunctivitis. This is common in urban areas with chronic air pollution. It is probably due to ozone, nitrogen oxides, and other irritants present in photochemical smog.

Acute Eye Injury

Serious eye injury due to trauma is common, especially due to certain industrial hazards and to automobile injuries. The eye is fairly well protected from blunt blows by the bones of the skull. An eye injury that results in hemorrhage or the slightest visual impairment requires immediate professional attention.

Eye injury due to corrosive or irritating chemicals requires immediate washing of the eye with large volumes of water. Immediate action taken prior to professional aid may save vision.

Blindness due to oxygen therapy in premature infants

Premature infants are often given oxygen therapy because they frequently suffer from respiratory distress. However, excessive oxygen has been found to cause the growth of vascular tissue into the vitreous humor. This growth is followed by the formation of scar tissue. This condition, known as retrolental fibroplasia, causes permanent blindness.

Blindness due to gonococcal infection

This disease is rare in adults but common in children. In fact, it used to be responsible for 12% of all blindness. Today, with the advent of prophylatic treatment, this figure has been reduced to less than 0.3%. This gonococcal infection occurs most commonly when the conjunctiva is contaminated when the fetus passes through the birth canal of an infected mother. Acute conjunctivitis develops, which progresses to corneal ulceration and scarring. Washing a newborn baby's eyes with a solution of silver nitrate has been found to kill any gonococci that may be present, and has become a routine procedure in most hospitals.

LESSON 33: THE SNELLEN VISION SCREENING TEST

RATIONALE:

Lesson 33 introduces the important Snellen vision screening test, which has long been used in screening populations for the presence of myopia and astigmatism. This lesson provides the background for students to administer the Snellen test to themselves as well as to elementary-school students during the field trip in Lesson 35.

OBJECTIVES:

The student will:

- define the terms screening test and visual acuity.
- state what the numerator and denominator stand for in the notation 20/100 (for example) on a Snellen chart.
- define the terms myopia, hyperopia and astigmatism, and state which of these disorders may be detected with the Snellen test.
- explain how room lighting and squinting can affect an individual's performance on the Snellen test.
- give an oral report on the eye condition assigned in Lesson 32.

SEQUENCE: Activity 32(conclude); ST-33

SUGGESTIONS:

1. Students are to present information gathered in Activity 32, based on their library research. This is discussed in the Instructor's Manual, Information on Activity 32.

2. The difference in the focal lengths of different people's eyes is demonstrated by the fact that a microscope that is in focus for one person may have to be adjusted by someone else looking at the same field. The alteration, by corrective lenses (eyeglasses), of where the image falls in the eye also explains why someone wearing eyeglasses who uses a microscope must re-adjust the focus after removing his or her glasses.

LESSON 34: (A) MEASURES OF CENTRAL TENDENCY

(B) TESTING VISUAL ACUITY

RATIONALE:

ST-34 discusses the concepts of mean, median and mode. These measures of central tendency are needed to evaluate the data collected when the students administer the Snellen test to elementary-school students. Also, these measures are useful in the statistical evaluation of data, and it is desirable that the students be familiar with them.

In LA-34 the students administer the Snellen test to one another. This is meant to serve as a practice experience, so that when they give the test to elementary-school students they will be familiar with the techniques.

OBJECTIVES:

The student will:

- define mean, median and mode and describe the kind of information given by each of these measures.
- administer the Snellen test to a fellow student.
- complete any preparations necessary for the field trip for administration of the Snellen test to elementary-school students.

SEQUENCE: ST-34; LA-34

SUGGESTIONS:

1. It is important that a certain amount of time be set aside during this lesson to organize the logistics of the field trip planned for Lesson 35. By this time you should have visited the elementary school and talked with the administration there and the teachers whose classes are to be involved in the vision-screening activity. At this time you will want to acquaint the students with what the testing situation is going to be like. This would include a description of the physical layout of the school. You may even wish to make a rough sketch on the chalkboard to help them visualize where they will be working.

Also, any questions about how to conduct the screening, how to record the data, etc., should be cleared up now. Each student should know what his or her role will be when they reach the elementary school. Students should be assigned a specific role that they will play in the vision screening, e.g., presenting the cards, positioning the child, etc. There will also be a need for someone to record the data, to escort the children from the classroom to the testing room, etc.

If there are students who are not involved in the above activities, they could be assigned the task of occupying the children who are waiting outside the testing room. The "occupying" could consist of having the Biomedical students administer some of the tests with which they have become familiar in this unit. For example, the pupil reflex and blink reflex tests from LA-5 could be used. The technique for mapping the blind spots, used in LA-8, might also be of interest. These activities are appropriate in that they are related to the anatomy and physiology of the eye. Should you decide to adopt this suggestion it will be necessary to "brief" all the students who will be involved on their responsibilities. Students involved in each test should also be advised to prepare a very simple explanation of the test they are performing to the elementary-school students.

When discussing how the data from the test are to be recorded, it would be a good idea to emphasize the importance of recording the child's name, sex and cases in which the child is already wearing glasses. (Students should also be reminded that the test is to be made without glasses.) It is important that all this information be recorded because the sex will not always be obvious from the name when

the data are analyzed. Also, the names will be needed so that the school may be informed as to those children who may possibly be in need of further screening or examination.

2. Prior to LA-34, the sets of cards that have been constructed should be checked to make sure that they have been accurately done and that the contrast on them is good. If the borders of the letters are not clearly delineated or the letters are not sufficiently "blacked in" this should be done now. Letters with insufficient contrast or ragged edges will compromise the accuracy of the test.

If you have made up sufficient sets of cards, the problem of having students with nothing to do during the field trip will be eliminated. If you have only a limited number of cards, then you will probably need to spend some time at this point thinking of activities that the "free" students can do with the elementary-school children before and/or after their vision has been tested. One suggestion on possible activities was mentioned earlier.

KEY--PROBLEM SET 34:

1. mode; maroon

2. median; 16.5

3. mean; 255 lb

INFORMATION ON LABORATORY ACTIVITY 34:

TEACHING NOTES:

1. The purpose of this activity is to give the students a chance to practice administering the Snellen test before they are required to give it to elementary-school students on the field trip.

2. Anticipated time: one period.

3. Each student should have the opportunity to administer the test to one other student, so that all students will be familiar with the procedure involved.

4. It is suggested in the Introduction to LA-34 that the students who are going to work in a specific group get together and decide what methods they are going to use in administering the test to elementary-school students. They could then use this same technique when administering the test to each other. We recommend that this procedure be followed since it will greatly increase the fluidity with which the students carry out their assignments on the day of the field trip.

5. The materials list calls for 6 sets of Snellen cards. It is suggested that you have the students construct these sets from one original set of cards. The cards may be cut out of large pieces of posterboard. If this is done, this activity becomes economically reasonable. If not, then you may need to make adjustments depending on how many sets of cards are available.

6. At the end of the activity, the data forms should be collected and given to the Mathematics instructor. He or she will need them for Mathematics Lesson 2.

MATERIALS: (for 6 set-ups)

6 sets of Snellen cards (hand-hold "E" set)

30 index cards, 3" x 5"

tape measure, yardsticks or meter sticks

light meter, calibrated in foot-candles (optional)

LESSON 35: FIELD TRIP TO AN ELEMENTARY SCHOOL

RATIONALE:

Lesson 35 consists of a field trip in which the Biomed students administer the Snellen test to school children. It provides a chance for students to learn something about their aptitude for a few health careers. The vision screening also provides the students with data to which some of the methods of statistical analysis that they have been learning in the Mathematics course will be applied.

OBJECTIVES:

The student will administer the Snellen test to a group of elementary-school children.

SEQUENCE: Field Trip

SUGGESTIONS:

1. You may want to review the activity with the students before they depart on the field trip, to be sure that everything is in order. A last-minute review of what everyone is going to do should help to ensure a successful trip.

2. The data obtained in Lesson 35 should be collected and given to the Mathematics instructor for analysis in Mathematics Lesson 2.

3. LA-36 requires that the students' lower back region be accessible. They should be warned a day in advance to wear appropriate clothing(i.e., skirts and blouses).

LESSON 36: (A) THE SENSES

(B) THE TWO-POINT THRESHOLD

RATIONALE:

This lesson and the next on the senses complete the treatment of the nervous system and its various roles in the body. In medicine, the testing of senses such as touch, pressure and vision provides useful information in diagnosis. ST-36 introduces students to the different kinds of sensory receptors and examines the importance of sensory adaptation. In LA-36, students compare the distribution of touch receptors in the skin on different parts of the body.

OBJECTIVES:

The student will:

- list the traditional five senses.
- list three senses other than the traditional five.
- define the term kinesthetic sense and state the function of this sense.
- define the term adaptation as it applies to sense receptors and give an example of this phenomenon.
- compare the touch sensitivity of the skin at body sites, using the two-point threshold test.

SEQUENCE: ST-36; LA-36

SUGGESTIONS:

1. Three optional procedures or demonstrations are provided below.

Touch Localization: The subject's hand is touched briefly with the pointed end of a pencil (the subject should be blindfolded). The subject then places the point of another pencil as close to the original point of stimulation as he can. The distance from the original point is measured with a metric ruler. The test is repeated at other areas of the hand (and at other body sites) to determine where touch localization is most accurate.

Aristotle's Experiment: Cross the right-middle and right-index fingers and place them on the palm of the left hand. Place a small shot or pea between the ends of the crossed fingers, and roll the shot about the palm of the hand. Describe the sensation.

Temperature Contrast: (a) Place one hand in a pan of water at 40 °C and the other hand in a pan of water at 20 °C. Wait half a minute until the initial sensations of warmth and coldness become less intense. Transfer both hands into water at 30 °C. Describe the sensation and explain. (b) Place one hand in water at 30 °C and the other hand in water at 45 °C. Wait a short time and transfer both to water at 10 °C. Describe the sensation and explain.

(In both cases, one hand feels warmer than the other. As discussed in Section 36-2, warmth and cold receptors are more responsive to abrupt changes in temperature than to a steady temperature. Consequently, when both hands are placed in the same pan, the receptors respond to the change in temperature and not to the temperature itself.)

2. The following discussion question may be of interest:

Many people have thought, at one time or another, that to be unable to feel pain would be wonderful. Do you agree or disagree? Why?

3. Adaptation is defined differently in this lesson than earlier in the curriculum. You may wish to review the distinction between the two definitions to avoid confusion. Adaptation is used in this lesson to mean the process by which a sense receptor reduces the number of nerve impulses it sends after the stimulus has remained constant for awhile. The term was used in Unit II, Lesson 3, to mean the evolutionary process of becoming more suited in structrue to a particular function. In both cases, adaptation refers to a beneficial change, but the Unit II usage implies a very gradual change that occurs over a period of many generations.

INFORMATION ON LABORATORY ACTIVITY 36:

TEACHING NOTES:

1. The purpose of this activity is to estimate the two-point touch thresholds of four different areas of the body. This measurement is an indicator of the relative number of pressure-sensitive receptors per unit area of skin.

2. Anticipated time: one to two periods.

3. Students should be advised a day in advance to wear a shirt or blouse that can be raised up enough to allow for testing the lower-back area.

4. To ensure sanitary conditions, you may wish to provide several beakers filled with 70% ethyl alcohol. Before testing the lip area, the probes can be dipped briefly in the alcohol.

5. The activity may be augmented in a variety of ways. Other skin surfaces may be tested (for example, the cheeks, neck, fingertips, arms and legs). It is possible to test whether handedness (that is, whether the subject is right-handed or left-handed) is associated with two-point threshold sensitivity by testing both hands of each subject. Another option is to compare the sensitivity of large hands versus small hands, or large bodies versus small bodies.

MATERIALS: (for 10 set-ups)

10 plastic drinking straws

10 small corks to fit ends of straws (#000)

80 map pins

10 mm rulers

10 blindfolds

ANTICIPATED RESULTS:

The students should find that the four areas ranked in order of decreasing sensitivity are the lips, the palm, the back of the hand and the back. Variation from these results should be expected, depending on how the test is administered, how the results are interpreted and individual differences in sensitivity.

The trends in sensitivity may be easiest to establish if the data for the entire class are compiled. There are a number of ways to do this, and students may suggest their own ideas for scoring the results. For example, the percentage of correct responses out of the total (ignoring control responses) could be calculated. These percentages are shown in the following table for a group of seven people to whom the test was administered.

From these data it is possible to estimate average values for the two-point thresholds by several methods. These values should be considered estimates since (a) a non-continuous measuring system is used (the pin heads gapped at .5, 1, 2 and 4 cm) and (b) assumptions must be made which are at best arbitrary.

For example, it might be assumed that the two-point threshold is the distance at which 50% of the responses are correct. If more than 50% of the responses are correct for a particular distance, it could be further assumed that the two-point threshold must be less than that distance. This reasoning, applied to the results given above, indicates that the average two-point thresholds for our subjects are as follows:

		DISTANCE BETWEEN PIN HEADS (cm)			
		.5	1	2	4
S	PALM	36	86	100	100
I	BACK OF HAND	36	36	50	100
T	BACK	21	29	36	57
E	LIPS	71	93	100	100

LIPS: less than 0.5 cm

PALM: between 0.5 and 1 cm

BACK OF HAND: approximately 2 cm

BACK: between 2 and 4 cm

A second and more detailed method of compiling the results is shown in the opposite table. For each distance and site, the total number of responses in three categories have been compiled.

	.5			1			2			4		
	++	+-	--	++	+-	--	++	+-	--	++	+-	--
PALM	1	3	3	5	2	0	7	0	0	7	0	0
BACK OF HAND	0	5	2	2	1	4	2	3	2	7	0	0
BACK	1	1	5	0	4	3	1	3	3	2	4	1
LIPS	4	2	1	6	1	0	7	0	0	7	0	0

(++): individuals who responded correctly to both tests at the distance indicated.

(+-): individuals who gave one incorrect and one correct response.

(--): individuals who responded incorrectly to both tests.

This table reveals a little more about the results than the table of percentages. For example, on the back of the hand, 36% of the responses were correct at distances of both 0.5 and 1.0 cm. However, as shown in the second table, none of the subjects responded correctly to both tests at 0.5 cm, while two of the subjects did respond correctly to both tests at 1.0 cm. From these results, it could be inferred (a) that sensitivity may decrease fairly steadily as the separation between the two points is decreased, rather than abruptly at the two-point threshold value, or (b) that two individuals may be decidedly more sensitive than others in the sample. Other interpretations are also possible depending on individual results.

ANSWERS TO DISCUSSION QUESTIONS:

1. See Anticipated Results.

2. See Anticipated Results. Variation between students should be expected.

3. By compiling the results of the class, it may be possible to show that females in general have slightly more sensitive skin than males. This difference may be related to body size.

4. Some areas of the body are used for wide varieties of tasks that require sensory precision. Consider, for example, the determination of texture by a single fingertip.

5. Hairs have special receptor cells at their base. When a hair is touched these cells are stimulated. These receptors would interfere with the procedure results.

LESSON 37: (A) THE SENSES OF SMELL AND TASTE
(B) TASTE THRESHOLDS
(C) REVIEW

RATIONALE:

Lesson 37 considers the senses of taste and smell. This treatment of the human senses concludes Unit IV's analysis of the functions of the body related to the brain and nervous system. The senses of taste and smell are also related to the Nutrition Unit in that they contribute to the selection of foods and to the initial phase of digestion (the phase involving salivation). In LA-37, students measure their taste thresholds for salt, sucrose and saccharin.

OBJECTIVES:

The student will:

- state which senses involve chemoreceptors.
- state the physical requirements for a substance to be tasted (solubility in water or fat) or smelled (volatility).
- measure his or her taste thresholds for salt, sucrose and saccharin.

SEQUENCE: ST-37; LA-37; Unit Review

SUGGESTIONS:

1. The following questions may be of use in initiating a discussion.

a. To which taste are we most sensitive? Can you suggest any reason why this might be advantageous? (Toxicologists have found that many poisons that occur in plants and animals are bitter. Since the bitter taste is generally unpleasant, we have a built-in protection against many poisons.)

b. What theory has been postulated to explain how we are able to perceive so many odors? (It has been suggested that many odors are actually mixtures of a small number of "primary" odors.)

2. It might be interesting to compare the odors of H_2O and H_2S. While pure water (H_2O) is devoid of any odor, the related compound hydrogen sulfide (H_2S) is a poison which is responsible for the obnoxious smell of rotten eggs. H_2Se, a compound of the element selenium, is also noxious and poisonous. Since sulfur (S) and selenium (Se) are in the same column of the periodic table as oxygen, and elements in the same column typically have similar chemical and physical properties, one might expect H_2O to also smell bad. (Or one might expect H_2S or H_2Se not to smell bad.)

You might want to add the curious fact that humans are somewhat unique among mammals in not being able to taste pure water. We share this distinction with rats. Cats, dogs and some primates, on the other hand, have distinct taste receptors for water. The pleasant taste that we sometimes associate with spring water is not due to water but to minerals and other dissolved substances present in the water.

3. The sense of taste is to a significant degree dependent upon the sense of smell. This point may be demonstrated in the following ways.

a. Instruct a subject that he will be blindfolded and given an unidentified fluid to drink while holding his nose. Then have the subject drink a small amount of orange juice and ask the subject to try to identify the fluid. (It is probable that the subject will describe the taste as sweet or sour but will not recognize that the fluid is orange juice. This is because the "orange" flavor is due to the aroma of a volatile substance known as octyl acetate.)

b. Feed a blindfolded subject pieces of chopped onion and apple in random order while the subject holds his or her nose. Ask the subject to state which substance has been given each time. (Because the flavors of apples and onions are due to the aroma of volatile compounds, the subject will have difficulty in

distinguishing between the two substances under the experimental conditions.) Pieces of radish and potato may also be used.

c. Feed a blindfolded subject a piece of pear while a piece of apple is held near the subject's nose. Ask the subject what he or she is eating. (The subject will probably state that the fruit is an apple because of the effect of the aroma of volatile compounds in the apple.)

d. Blindfold the subject and ask the subject to distinguish the odors of (1) oil of cloves, (2) oil of peppermint and (3) tincture of camphor when vials of these substances are held close to the nose.

Have the subject occlude one nostril and smell the tincture of camphor until the odor can no longer be detected. Immediately have the subject attempt to distinguish, with the adapted nostril, between oil of cloves and oil of peppermint. (The subject will have difficulty distinguishing between the two. One possible explanation of this observation is that volatile camphor molecules have saturated the chemoreceptors that detect odors.)

4. Nerve impulses conveying information on smell go from the nasal cavity to the olfactory bulbs of the brain. You may wish to remind students that they observed the olfactory bulb in the animal brain dissection activity, LA-1.

5. Students may be interested in learning that saccharin has been used to measure circulation time. (Bitter-tasting substances such as decholin are now more frequently used because people are more sensitive to bitter tastes than to sweet tastes.) Sometimes physicians want to know the rate of blood flow in blood vessels in cardiac patients. A slower than normal rate of blood flow might suggest the need for digitalis therapy to augment the cardiac output. The rate may be determined by injecting saccharin into a peripheral vein of the arm near the elbow and asking the patient to state when a sweet taste is detected. A normal range for blood flow, from arm to tongue for young patients is 0 to 16 seconds. For an elderly patient, a circulation time of 20 seconds is not considered abnormal.

6. The five traditional senses, especially the senses of taste and smell, are clearly of great importance in determining our attitudes toward foods and are therefore important in nutrition. You may wish to provide one or more activities to explore the relationships between foods and the senses. Some possibilities are outlined below for optional use. Many other variations are possible.

a. Have the students form groups of two or larger to evaluate the relationship between the senses and food attractiveness. Each group should have at least one subject and at least one observer.

b. Each subject can be provided with foods to test one at a time. Blindfolding the subject may be necessary to avoid biases. Each subject may compare a series of similar foods, for example, a variety of breakfast cereals or similar beverages or margarines. You or the students could select from many other kinds of food to score. Two or more groups could evaluate the same foods.

c. To quantitate the activity, you could have the students score their observations on foods much as a taste panel does. For example, the students could rate saltiness--they might equate 1 to no detectable taste, 2 to a barely detectable taste, 3 to a slightly salty taste, 4 to a moderately salty taste and 5 to a very salty taste. Similar scales can be made for sweetness, sourness, bitterness and odor. The class could also define standards for what is appealing in a particular food. For some foods, students might be able to score "feel" (consistency) and "sound." (The consistency of a food may be important in determining how appetizing it is. For example, crispiness may be a plus for a food. Likewise, the sound of a "fizz" or the sound of a food being chewed may be related to the attractiveness of a food.) The blindfolds could be removed at times to evaluate the appearance of a food.

d. If the activity is treated in a quantitative way, then the class data could be analyzed for means, medians and modes. Chi-square tests may be applicable to pairs of foods compared.

e. In addition, the class could be divided into three major groups-- a

control group, a blind group and a double-blind group. In this way, the difference between a blind experiment and a double-blind experiment could be demonstrated.

7. In order to do some of the problems in the Unit Review Set, the students will need a table of trigonometric functions. Such a table is located at the end of the Unit IV Biomedical Mathematics Student Text.

INFORMATION ON LABORATORY ACTIVITY 37:

TEACHING NOTES:

1. The purpose of this activity is to give the students an opportunity to determine their taste thresholds for salt, sucrose and saccharin.

2. Anticipated time: two periods.

3. If your tap water is reasonably low in salt content, you may wish to use tap water throughout this activity. If your area has "hard" water, or water that tastes slightly salty or smells of chlorine, then distilled water is needed.

4. The subjects should be allowed to move the test solution around in the mouth before making a decision.

5. Threshold sensitivities, as you might expect, are subjective and quite variable. In this activity an attempt is made to control the subjectivity to some degree by not allowing the subjects to know what concentration they are tasting. Note that the taste threshold depends in part on the amount of solution in the mouth. Consequently, the students should not place more than three drops on the tongue in any trial.

6. Other "tastes" may be tested using this procedure. Recommended substances are acetic acid and quinine sulfate, with thresholds of approximately .02 M and 8×10^{-6} M respectively. Students should make their dilutions beginning with the following solutions.

.16 M acetic acid: prepare by adding 11.3 ml of glacial acetic acid to sufficient water to make 1250 ml final volume.

64×10^{-6} M quinine sulfate: prepare by dissolving 0.63 g quinine sulfate in 100 ml of water; dilute 10 ml of this solution with water to a final volume of 1250 ml (the remaining 90 ml may be discarded).

MATERIALS: (for 10 set-ups)

1.8 g sodium chloride (NaCl)	60 medicine droppers
13.7 g sucrose (table sugar)	90 paper cups, 6- to 8-oz
1 to 2 saccharin tablets	10 blindfolds

PREPARATION OF REAGENTS:

.032 M NaCl: Dissolve 1.8 ± .1 g sodium chloride in sufficient water to make a final volume of 1250 ml.

.032 M sucrose: Dissolve 13.7 ± .1 g sucrose in sufficient water to make a final volume of 1250 ml.

64×10^{-6} M saccharin: Saccharin tablets may be purchased from supermarkets or drugstores. The amount of saccharin in each tablet should be indicated on the label of the bottle, either as plain saccharin or sodium saccharin. To prepare the solution dissolve one saccharin tablet in X ml of water. The value of "X" may be

calculated by multiplying the amount of saccharin in grams (Y) contained in each tablet by the appropriate factor given below.

for plain saccharin: $X = (85.3 \text{ liters/g})Y$

for sodium saccharin: $X = (64.8 \text{ liters/g})Y$

If the value of X is less than 1250 ml, the solution ingredients should be doubled so that there is enough solution for 10 set-ups.

ANTICIPATED RESULTS:

Typical threshold concentrations are listed below.

NaCl: 8×10^{-3} M

sucrose: 16×10^{-3} M

saccharin: 16×10^{-6} M

Average threshold concentrations for the class may be estimated by compiling the data for the entire class. Information concerning the analysis of these data may be found in the Anticipated Results for LA-36.

ANSWERS TO DISCUSSION QUESTIONS:

1. Taste thresholds are similar for NaCl and sucrose for most people. Some may identify NaCl at a lower concentration. The threshold concentration for saccharin is considerably less than that for either NaCl or sucrose.

2. Molecular mass NaCl = 58.4 amu.

Molecular mass sucrose = 342.3 amu

Since we are concerned with the number of molecules per sample, solutions containing equal masses would have almost six times as many molecules of NaCl as of sucrose.

3. Depends upon the individual results obtained. However, our results indicate that saccharin may be as much as 1000 times as sweet as sucrose.

4. The value given for quinine sulfate was 8×10^{-6} M. The threshold concentration for saccharin should be slightly higher than that for quinine sulfate.

5. After preparing the dilutions, the labels would be covered and the cups mixed up. The samples would be applied to the subject's tongue in random order so that the tester did not know which solutions were being tested. After the test was completed, the labels would be uncovered and compared to the subject's responses.

6. 1.87 g NaCl/liter 1.10 g sucrose/100 ml .0012 g saccharin/100 ml

KEY--UNIT REVIEW SET:

1. a. Controls hunger; thirst; regulates body temperature; monitors Na^+ concentration of the blood; controls secretions of the pituitary gland hormones, such as those responsible for growth.

b. Controls heart rate, respiration and digestive functions.

2. a. The mouth and hands.

b. Both have many muscles for detailed and complex movement. Many nerves and a sufficient area of the brain are needed to control these muscles.

3. See Figure 1, ST-2.

4. CNS includes the brain and spinal cord. Peripheral nervous system includes all the nervous tissue outside the CNS.

5. A neurotransmitter secreted by the terminal of the first neuron causes the next neuron to fire.

6. Beta--ordinary thought.

Alpha--eyes closed and mind relaxed.

Theta--awake adults with periods of emotional stress or resting children.

Delta--adults during sleep or in awake babies.

7. a. Alcohol consumption; excess intake of coffee, tea or cola; emotional stress (epileptic seizures also occur spontaneously).

b. With mild sedatives or other drugs and by counseling the patient to avoid factors that may trigger a seizure.

8. The autonomic nervous system is composed of nerves which extend from the spinal cord and brain to organs of the body. It controls vital body functions such as heart rate, salivation, peristalsis and respiratory rate. The CNS is composed of the brain and spinal cord. It controls conscious thought, speech and other actions such as muscular movement.

9. a. A technique by which information about an internal body process is relayed through external equipment to the subject and the subject learns to control consciously that process.

b. Migraine headaches can sometimes be controlled when the patient is taught to raise the temperature of a finger. Tension headaches may be helped when the patient relaxes the frontalis muscle. Other examples are possible.

10. a. Knee-jerk, plantar, ankle jerk, biceps, triceps, brachioradialis, pupil, blink.

b. Some reflexes are protective; some are regulatory. Blinking protects the eye, coughing protects one from choking when food enters the trachea and salivating prepares for digestion. Other reflexes regulate the heart and respiratory rates.

11. CSF is cerebrospinal fluid. It is produced within the brain and fills the ventricles of the brain and the space between the innermost and middle meninges.

12. Red blood cells--suggests possible cerebral hemorrhage.

Gamma globulins--suggests possible multiple sclerosis.

Total proteins--may suggest other brain diseases, as well as cerebral hemorrhage.

13. Cerebral hemorrhage

14. a. Formation of a blood clot within a blood vessel in the brain.

b. Atherosclerosis in a blood vessel sometimes causes a clot to form.

15. Headaches, visual-field defects, slowly developing symptoms.

16. Visual-field defects may help a physician determine which area of the brain is affected since the optic nerves pass through different parts of the brain. Increased intracranial pressure, which can be caused by a brain tumor, can affect the appearance of the optic disk. Hypertension may be detected by observing the blood vessels in the eye with an ophthalmoscope.

17. X-rays may show tumors that contain calcium deposits, or they may show damage to skull bones; angiograms may show changes in the shape of arteries as a result of tumors; echoencephalograms may show displacement of the "midline" peak, which can be caused by a tumor, cerebral hemorrhage or some other disorder.

18. 2-NAND

19.

Findings				Disease
d	g	h	p	strep throat
1/0	1	0	1	1
all others				0

Findings				Disease
d	g	h	p	bacterial pneumonia
1	0	1/0	0	1
all others				0

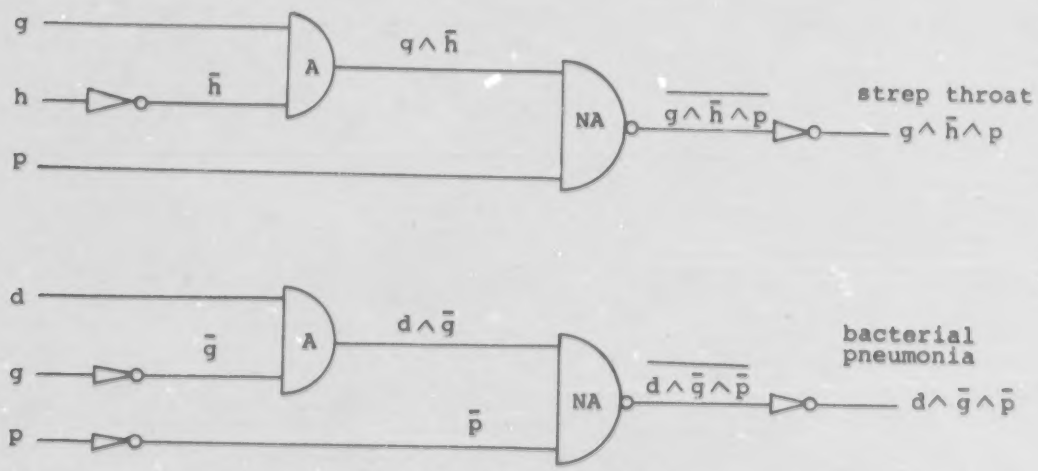
Findings				Disease
d	g	h	p	bronchitis
1/0	0	1	0	1
all others				0

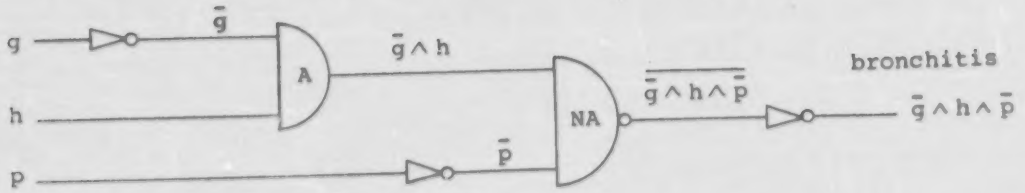
20.

Findings				Diagnoses
d	g	h	p	
1/0	1	0	1	strep throat
1	0	1/0	0	bacterial pneumonia
1/0	0	1	0	bronchitis

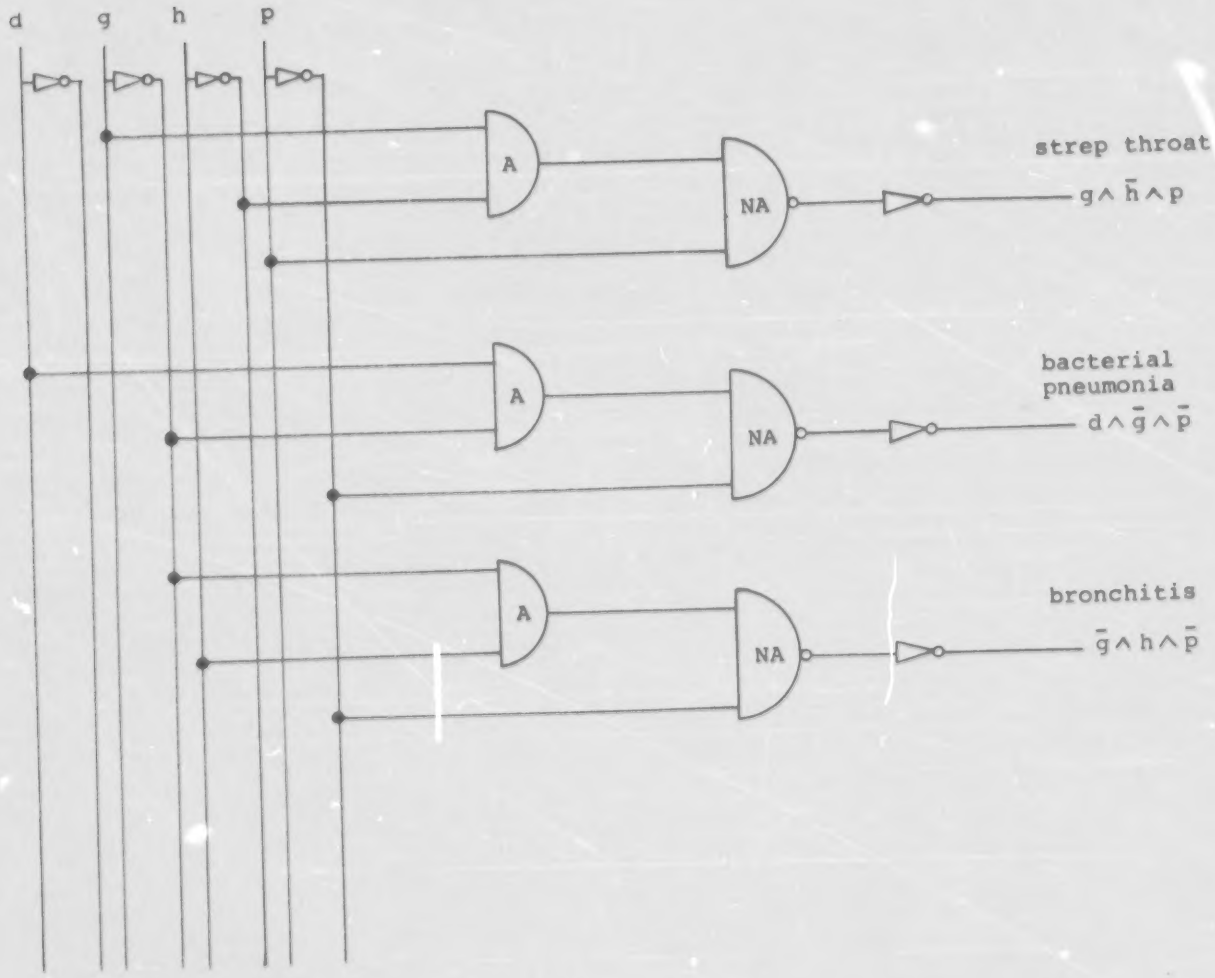
21. strep throat: $g \wedge \bar{h} \wedge p$
bacterial pneumonia: $d \wedge \bar{g} \wedge \bar{p}$
bronchitis: $\bar{g} \wedge h \wedge \bar{p}$

22.





23.



24. The computer can only indicate which of the diseases it is programmed for are possible diagnoses. The patient could always have another disease that presents findings similar to those associated with one or more of the diseases in the computer program.

25. Plant drugs--digitalis, morphine, quinine.

Animal drugs--thyroxin, insulin.

Neither--aspirin, kaolin.

26. No. Penicillin only kills bacteria in the process of cell division. It kills bacteria by interfering with cell-wall synthesis.

27. Vasodilator.

28. Anesthetic (or general anesthetic).

29. Laxative or cathartic.

30. Depressant.

31. Antibiotic.

32. Symptoms of patient, patient's medical history, results of physical examination including clinical findings and signs, possible side effects, contraindications, appropriate dosage, best way to administer the drug, cost of drug, availability of drug, special instructions to the patient.

33. (a) High concentration of salt or sugar.

(b) Oxidizing agents, formaldehyde.

(c) Fluoride.

34. Interfere with cell-wall synthesis, destroy the cell membrane, interfere with protein synthesis, interfere with synthesis of nucelic acids.

35. a. A drug treatment that works for psychological reasons and not because of tne physical or chemical effects of the drug or treatment itself.

b. Used in medical research on drug evaluation. Sometimes used while waiting for diagnostic tests, when an unidentified condition does not seem serious enough to warrant further tests. Sometimes used when an identified or unidentified condition cannot be cured by drugs.

36. Malnutrition and cirrhosis of the liver.

37. Addiction--condition in which withdrawal of the drug produces physical symptoms.

Habituation--psychic dependence on a drug; craving for its use to produce pleasure or abolish discomfort.

38. Opiates--CNS depressant; early use to stop diarrhea.

Cocaine--local anesthetic and vasoconstrictor on the mucous membranes of the nose and throat.

39. Opiates--cause addiction, tolerance and withdrawal symptoms.

Cocaine--disagreement on addiction; produces tolerance and withdrawal symptoms.

Marijuana--does not cause addiction or withdrawal symptoms; disagreement on tolerance.

40. a. Displacement at right angles to the direction of the wave.

b. Displacement in the same direction as that of the wave.

c. Longitudinal.

41. Standing: vibrating vocal cords, vibrating strings of a guitar, laser, vibrating air column in a trombone.

Traveling: voice, sounds of movement.

42. Loudness (in db) of a pure tone of a given frequency that a subject can barely hear.

43. More nerve impulses per second are transmitted.

44. a. Conduction impairment and perception impairment.

b. Conduction impairment includes factors which affect the transmission of sound vibrations to the inner ear. These include the build up of ear wax, which prevents the eardrum from vibrating; damage to the bones of the middle ear, which makes them unable to vibrate; and otosclerosis of the oval window. Lower frequencies are affected the most.

Perception impairment includes factors which affect hearing once the sound vibrations have reached the inner ear. Such defects are commonly the result of: damaged hair cells in the cochlea, failure of cells in the organ of Corti to convert sound vibrations into nerve impulses, and failure of the hearing nerve to conduct impulses from the organ of Corti to the hearing center in the brain. Causes include recurrent exposure to noise in the 1,000- to 3,000-cycle range, exposure to high frequency, loud sounds, damage to the hearing nerve and gradual impairment of circulation due to atherosclerosis in older people. High frequencies are affected the most.

45. a. Adjusting the shape of the vocal tract to produce different sounds.

b. Movements of the lips, tongue, soft palate, and jaws.

46. Vocal cords and vocal tract.

47. Positions taken by the tongue as it moves through the extreme positions required to form vowels.

48. Speed = frequency x wavelength
= 700 cycles/sec x 1.8 meters/cycle = 1260 meters/sec.

49. $c = 3.00 \times 10^8$ m/sec.

50. a. From about 400 nm to 700 nm.

b. From about 7.5×10^{14} cps to 4×10^{14} cps.

51. Both may be described in terms of waves. (Other answers are possible that are less fundamental. For example, both may be diffracted.)

52. Sound requires a medium while light does not. Sound may be heard even when there is a barrier between the source and the observer, while light cannot be seen.

53. They will be in phase if the difference in distance is a whole number of wavelengths. They will be completely out of phase if the difference in distance is half a wavelength plus any whole number of wavelengths.

54. A light microscope may not be used to form images of objects less than one wavelength in size.

55. a. Monochromatic green consists of those wavelengths of the spectrum that appear green to the eye. The band of wavelengths is relatively narrow.

b. No.

56. Refraction.

57. $n = 1.414$.

58. $n = 1.880$.

59. $c_{\text{vacuum}} = 3.0 \times 10^8$ m/sec.

60. Slower.

61. As an object comes closer to the lens, d_o decreases and $\frac{1}{d_o}$ increases. Since the sum $(\frac{1}{d_i} + \frac{1}{d_o})$ is a constant $(\frac{1}{f})$ the $\frac{1}{d_i}$ term must decrease. For $\frac{1}{d_i}$ to decrease, d_i must increase.

62. A real image is inverted and on the opposite side of the lens from the object. A virtual image is not inverted and on the same side of the lens as the object.

63. When the object distance is less than the focal length, a virtual image may be formed. Otherwise, a real image is formed.

64. a. 30.3 cm

b. 50.5 cm

65. The greater the radius of curvature the longer the focal length.

66. The greater the difference between indices of refraction at a boundary the more light is bent and consequently the shorter the focal length.

67. Light is bent the most at the air-cornea boundary because the difference between indices of refraction is greatest there.

68. a. d_i

b. f

69. To focus on nearer objects, the ciliary muscles become more tense. The effect is to decrease the focal length of the lens and bring the image of the object into focus on the retina. Conversely, to focus on distant objects, the ciliary muscles relax to increase the focal length of the lens.

70. a. c
b. r
c. r at night (c during the day)
d. r
e. r
f. c
g. r
h. r
i. r

71. See ST-31, Figure 1.

72. If the eyeball is too short, the accommodative powers of the lens will not be adequate to focus an image on the retina. The image distance will be longer than the eye and an unfocused image will be formed on the retina.

73. If the eyeball is too long, the image distance for far objects will be shorter than the eye and an unfocused image will be formed on the retina. However, a myopic subject will be able to see close objects because the image distance for close objects is longer.

74. A-e; B-d; C-f; D-g; E-b; F-h; G-i; H-c; I-a; J-j; K-m; L-l; M-k

75. a. F; b. T; c. F; d. T; e. F; f. F; g. F; h. F; i. T; j. T; k. F; l. T

76. Farsightedness (hyperopia).

77. Hyperopia, myopia, astigmatism.

78. Orientation, position, and movements of bones and joints.

79. Adaptation is the process by which a sense receptor reduces the number of nerve impulses it sends, after a stimulus (such as heat or touch) has been present for a time.

80. a. A volatile substance is one which readily diffuses into the air at room temperature.

b. Molecules of a substance must enter the nasal cavity with air if it is to be smelled. This happens readily if the substance is volatile.

81. Amperes, ohms, volts.

82. An electrical potential energy difference must exist between electrons. There must be a source of energy to raise the potential energy of the electrons from a low to a high level. Also, there must be a continuous path along which the electrons can move.

83. Smaller diameter, greater length and higher temperature all increase the resistance.

84. An insulator is any substance that does not conduct electric current under normal conditions. A conductor is any substance that readily permits the flow of electric current.

85. See Section B-3.

86. a. Increases; b. Decreases.

87. a. $\text{current} = \frac{\text{voltage}}{\text{resistance}}$ b. $I = \frac{V}{R}$

88. When placed in a circuit, the resistance of the rheostat can be changed, thus increasing or decreasing the current.

89. a. In AC, the current moves first in one direction and then in another. In DC, the current moves in only one direction.

b. The voltage may be adjusted more easily.

90. An electrical device that has part of its electrical circuit connected by a conductor to the earth.

91. a. By being connected to both of the two contacts in an electrical outlet, or by being connected to the ungrounded wire of an electrical device and a conducting surface in contact with the ground.

92. If excessive current flows through a wire, the wire can become so hot that it will cause a fire. If, however, there is a fuse in the circuit, the heat will cause the fuse to melt and break the circuit.

SUPPLEMENTARY LESSONS ON ELECTRICITY

LESSON A: INTRODUCTION TO CURRENT ELECTRICITY

RATIONALE:

The fundamentals of current electricity are introduced so that the students can appreciate the importance of the role of electricity in the modern world, particularly in health science. In addition, the study of current and voltage provides preparation for the treatment of Ohm's Law (Section C), electrical phenomena in the body (Section D) and electrical safety (Section E). In LA-A, simple electrical circuits are constructed which have been chosen to complement the discussion in ST-A.

OBJECTIVES:

The student will:

- state the relationship between electricity, energy and electrons.
- describe the physical nature of current.
- define the units (amperes) associated with current.
- describe the role of voltage (the potential difference between two points in an electrical system) in causing the flow of current.
- state three necessary conditions for electrons to flow.
- assemble simple electric circuits involving light bulbs, wires and various voltage sources.

SEQUENCE: ST-A; LA-A

SUGGESTIONS:

1. The lessons on electricity are intended to be usable at any point prior to beginning Unit V. However, the five lessons should be taught as a group in order to derive maximum benefit. It might be good to keep this sequence available for a situation in which students raise questions about electricity--the sequence may then be used to help the students find the answers.

2. You might start off a discussion of Lesson A by asking students, "How have you used electricity today?" The list could be tabulated on the chalkboard, and it might turn out to be longer than one would expect. This exercise would supplement Sections A-1 and A-2.

3. Students may be curious to know the distinction between "electricity" and electronics." Originally, electronics referred to the study of the movement of electrons in such devices as cathode-ray tubes and vacuum tubes. In a vacuum tube, electrons move through space from one metal plate to another, depending upon how the plates are charged. Such vacuum tubes found many uses as specialized "electronic" instruments were developed. The term "electricity" has applied more generally to the study of charged particles, particularly the movement of electrons in solid conductors such as wires (as examples, "electric" light bulb or "electric" heater).

In recent years, many vacuum tubes have been replaced by solid state devices (transistors and integrated circuits). Consequently, electronics now applies to more than just the control of the motion of electons in a vacuum. In practice, electronics has come to include most types of complex electrical instrumentation (television, calculators, computers, etc.) while electricity still applies to simpler devices (appliances, motors, light bulbs).

4. A few students may be bothered that an excess of electrons corresponds to a negative charge while a deficiency of electrons corresponds to a positive charge. If they have forgotten their Year I chemistry, their intuition might suggest the

opposite. Remind them that electrons are negatively charged, so that an excess of negative charge corresponds to a net negative charge.

5. You may wish to set up a simple circuit to accompany the discussion of Sections A-3, A-4 and A-5. A battery may be connected to a light bulb as one example. Ask the students why the bulb lights--then develop the idea of energy conversion from chemical energy in the battery, to kinetic energy of the moving electrons, and to light and heat energy in the light bulb.

6. You may wish to review the general concept of energy and forms of energy. These were treated briefly in Unit II, Lessons 22 and 23. You may wish to have students review these lessons prior to or during their study of electricity.

7. The subject of electrical energy is one of great current concern from the standpoint of cost, availability and environmental impact. You may wish to expand in this direction. We will not have occasion to treat these subjects in any depth because they do not relate to our biomedical theme.

8. An example of a wet cell commonly used is the automobile battery Although these batteries are slightly different from the cells made in the activity, they operate on a similar principle.

9. Since gravitational potential energy is a part of the fluid-flow analogy used in ST-A, you may wish to discuss briefly some of the differences between gravitational and electrical interactions. Unlike electrical force, gravitational attraction occurs between any two objects. The strength of the gravitational attraction depends on the masses of the objects, and not on the charges. Gravity cannot cause two objects to repel each other, as occurs when two objects of like electrical charge are placed close together.

10. It may be useful to point out to the class that the use of letters to indicate parts of this sequence merely indicates that the sequence has no particular connection to the content flow of the remainder of the unit.

INFORMATION ON LABORATORY ACTIVITY A:

TEACHING NOTES:

1. The purpose of this activity is to provide a simple introduction to some of the properties of electric circuits. Three different voltage sources are used: a dry cell, a simple voltaic cell (i.e., a "wet" cell) and the BIP. The activity reinforces a number of concepts that are discussed in ST-1 such as voltage, current, circuits and energy.

2. Anticipated time: 2 to 3 periods.

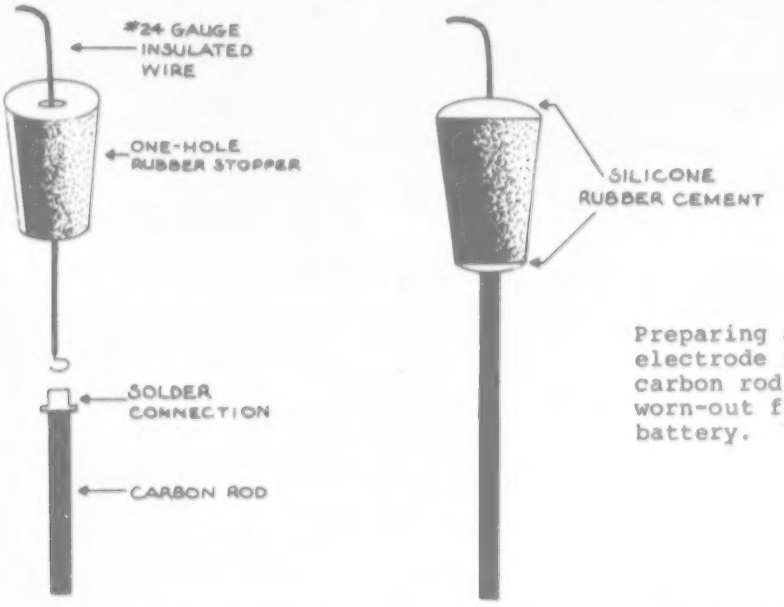
3. The students should be cautioned to avoid leaving the zinc electrode in the wet cell. When left in an acidic solution, the electrode deteriorates fairly rapidly, and loses the ability to provide the current necessary to light the bulb. It is often helpful to clean the electrodes when dry with some very light sandpaper (grade approximately #400)

4. The recommended connecting wire is the #24-gauge plated wire which is supplied with the BIP. The light bulbs are available through most electronics stores; they may be specified as "type #40, 6.3V miniature lamps." (Note: one of these bulbs is supplied as standard equipment with each BIP.) The light-bulb receptacles may be purchased in a number of varieties from electronics stores and laboratory supply houses.

5. The carbon and zinc electrodes are available from various supply houses. Two sources, Central Scientific Company (Cenco) and Sargent-Welch Scientific Company are listed below. The carbon electrodes specified all work equally well; the electrodes mounted in rubber stoppers have the advantage of being suitable for use in solution conductivity (Unit I, LA-24) and electrolysis (Unit I, LA-35) activities.

ELECTRODE	DESCRIPTION	CENCO CATALOG NUMBER	SARGENT-WELCH CATALOG NUMBER
Zinc	Flat, 22 x 125 mm	79306	2206
Carbon	Flat, 19 x 125 mm	79292	2218
Carbon	Round, 6 x 125 mm	79308	2208
Carbon	Round, mounted in #0 rubber stoppers	81255	2374

Carbon electrodes may also be obtained by opening wornout batteries and lifting out the center post. If this is done carefully, the metal cap that covers the end of the carbon rod will stay in place so that it can be soldered to a connecting wire. The electrode may be mounted in a #00 or a #0 one-hole rubber stopper; the stopper may then be sealed with silicone rubber cement, which prevents corrosion of the soldered connection by ionic solutions. The electrodes may be stored in test tubes to prevent breakage.



Preparing a carbon electrode using the carbon rod from a worn-out flashlight battery.

6. If time permits, the activity may be augmented with a simple investigation of conductivity. A number of different materials may be connected one at a time in series with the BIP and a light bulb in order to determine which substances conduct current the best. Suggested materials include copper wire (or other highly conductive wire), nichrome wire, coins, glass, plastic, rubber and various solutions such as vinegar, water and a solution of sodium chloride. The better the conductor, the more brightly the light bulb should glow. If the activity is augmented as described here, it is essential that the students be familiar with the concepts of resistance and conduction introduced in ST-B. (Further information on solution conductivity may be found in Unit I, LA-24.)

MATERIALS: (for 10 set-ups)

- 20 batteries, 1.5V, size C or D
- 50 feet connecting wire, 24-gauge, solid wire, insulated
- 5 to 10 wire cutter-strippers
- 20 light bulbs, #40, 6.3V, miniature

10 beakers, 50-ml

10 graduated cylinders, 100-ml

10 zinc electrodes

10 carbon electrodes

20 light-bulb holders

17.7 g potassium dichromate ($K_2Cr_2O_7$)

16.8 ml sulfuric acid (H_2SO_4), concentrated

20 alligator clips

5 to 10 screwdrivers

10 BIPs

PREPARATION OF REAGENTS:

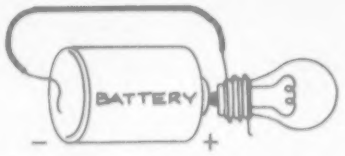
Potassium dichromate, 0.2 M: 17.7 ± 1.0 g $K_2Cr_2O_7$ + sufficient water to make 300 ± 10 ml of solution. Stable indefinitely.

Sulfuric acid, 1.0 M: Add 16.8 ± 1 ml conc. H_2SO_4 to 250 ml of water. Dilute to a final volume of 300 ± 10 ml. Stable indefinitely.

ANTICIPATED RESULTS: (See Answers to Procedure Questions.)

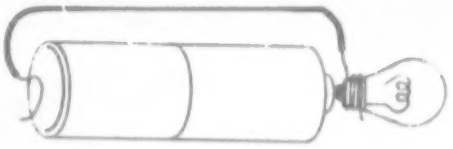
ANSWERS TO PROCEDURE QUESTIONS:

1. The two connection points on the light bulb are the threads and the tip. Wires connected between these points and the battery terminals should cause the bulb to glow. The connections are easier to make if one of the wire leads is wrapped around the threads of the light bulb. (Note: the bulb will also light if it is touched to the opposite terminal as shown in the diagram.) When the circuit is closed, electrons move through the wire and the light-bulb filament toward the battery's positive terminal.



Connecting a light bulb to a battery.

2. The light bulb glows more brightly if it is connected to two batteries as shown in the figure opposite.


A circuit with two batteries.

3. Two batteries of the same voltage when connected as shown above produce a greater voltage than one battery. The higher voltage causes more current to flow. This means that more electrons move through the filament per unit time, providing energy that can be converted into light.

4. If one of the batteries in the circuit shown above is reversed, the bulb does not light.

5. Tiny bubbles from the zinc electrode should be noticeable; the carbon electrode remains intact. Generally, the intensity of the light decreases after the cell has been operating for a minute or longer.

6. Answers will vary, depending on the type and condition of the dry cells, surface area of electrodes in the wet cell, etc. The wet cell should provide a light intensity similar to that provided by one dry cell.

7. The greater the voltage, the brighter the light from the lamp.

8. See answer to Question 6.

9. The BIP lights the bulb more brightly than a single battery.

10. The BIP produces a higher voltage than a single flashlight battery. In fact, the BIP produces 5 volts with this programming, which is equivalent to more than three flashlight batteries.

11. This depends upon what the voltage source is being used for.

12. The BIP produces a higher voltage and has the advantage of being able to produce a constant voltage indefinitely (as long as it is plugged in). Batteries

wear out eventually, but have the advantage over the BIP of being portable, making them suitable for use in flashlights, automobiles and transistor radios.

13. No.

14. The electrons flowing through the circuit are given energy by the voltage source. This energy is converted into light and heat as the electrons pass through the light-bulb filament. With two bulbs in the circuit, there is less energy available per light bulb than with only one bulb. Consequently, the bulbs glow less brightly. (If students have read Section B by this time, a better explanation is that the increased resistance causes a reduction in current.)

15. It goes out.

16. Removing a light bulb creates an open circuit; the electrons no longer have a continuous path along which to flow.

17. Any differences noted should be negligible.

18. No.

19. Removing one bulb does not break the circuit containing the second bulb.

20. Parallel wiring. If one bulb burns out, the others continue burning.

LESSON B: RESISTANCE, CONDUCTORS AND INSULATORS

RATIONALE:

An understanding of the phenomenon of electrical resistance is necessary for even a limited understanding of electricity, and prepares the students for the discussion of Ohm's law in Section C. Conductors, insulators and electrical symbols are also introduced to provide further background information.

OBJECTIVES:

The student will:

- define resistance and state the unit of resistance (the ohm).
- indicate how the resistance of a wire is affected by the diameter, length and temperature of the wire.
- distinguish between insulators and conductors, and indicate how these materials are used in electrical circuits.
- identify the following electrical symbols used in diagramming electrical circuits: connected wires, unconnected wires, light bulb, resistor, switch, voltage source.

SEQUENCE: LA-A (conclude); ST-B

SUGGESTIONS:

1. The students may be interested in what a lightning rod is and how it works. Lightning rods are good conductors which are in contact with the ground. Most of the current from a lightning bolt striking a house travels through the low-resistance rod to the ground. A lightning rod thus diverts almost all the current away from the high resistance of the house, and consequently prevents fires or other damage.

2. Students may be curious to know how the transistor permitted miniaturization of large circuits. As indicated in Lesson A, Suggestion 3, vacuum tubes were the principal components in many types of early instrumentation. Vacuum tubes typically range in size from 1" to 4" in length. Transistors, which began replacing vacuum tubes in the 1950's, are approximately 1/4" in diameter. The silicon wafer inside the transistor permits the same electrical operations as the vacuum tube. Currently,

a large number of circuit components can be consolidated into integrated circuits. These devices can incorporate thousands of transistors into a tiny silicon wafer.

3. The references to electrical components such as resistors, diodes, integrated circuits and switches will seem less abstract if the students can see these components in an actual circuit. You might, for example, expose for viewing the inside of the BIP as explained in Section 7-2 of the BIP Manual. The manual also has diagrams which indicate where certain components are located. An instructor who teaches electronics in your school could be very helpful in presenting this option.

4. The problem set is based both on this and the preceding lesson. The questions are probably more suitable for group discussion rather than for homework. You might have the students discuss the problems in small groups for a while and then have them discuss the questions as a class.

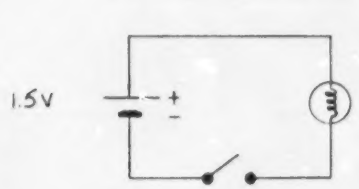
5. Section B-1 points out that the resistance of a wire increases with temperature. This is a general characteristic of metals, but not of all materials. In semiconductors, for example, resistance is inversely related to temperature. Such is the case with the BIP thermistor, which is made of semiconducting material.

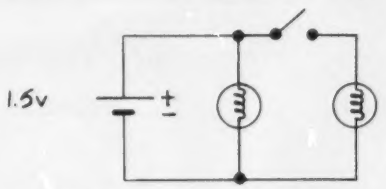
KEY--PROBLEM SET B:

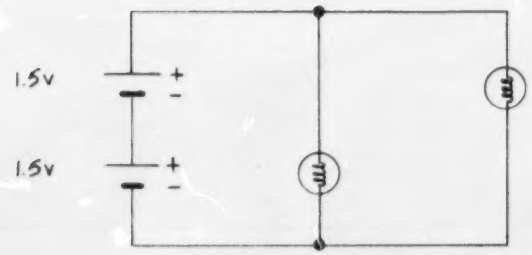
1. a. electrons; b. wire; c. current; d. voltage; e. amperes; f. battery; g. switch; h. resistance

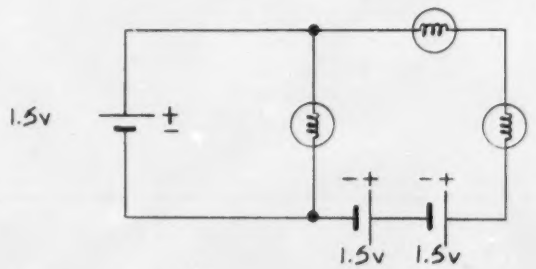
2. Chemical energy produces an electrical potential energy difference between the battery terminals. The electrons moving through the wire have kinetic energy which is converted into light and heat energy in the light bulb.

3. Equivalent arrangements of the following are acceptable.









4. (a) As discussed in Section B-1, the resistance of a long wire is greater than the resistance of a short wire. Therefore, the electrons can lose significant amounts of energy while flowing through a long extension cord. Electrons reaching the appliance have less energy available to power the appliance.

(b) The performance of the device can be improved by using a better conductor in the cord (for example, copper instead of aluminum wire), or by increasing the diameter of the wire. The voltage can also be increased.

5. Number of electrons per second = 10,000 amperes x $(6.24 \times 10^{18} \frac{\text{electrons/sec}}{\text{ampere}})$

$= 6.24 \times 10^{22}$ electrons/second

6. Current refers to the movement of electrical charge. Amperes are the units that are used when measuring current.

7. (a) OFF The circuit is not closed. The electrons cannot flow in a complete loop from the negative to the positive terminal of the voltage source. The voltage across the light is zero volts.

(b) ON The two voltage sources work together to produce a total voltage of 6V.

(c) OFF In this case, the voltages of the two batteries exactly offset one another so that no current flows in the circuit. The potential difference across the light is zero volts.

LESSON C: OHM'S LAW

RATIONALE:

Ohm's Law is a central concept in any study of electricity. It shows the relationship between current, voltage and resistance. In LA-C, the students study the relationship between current and resistance when voltage is kept constant. ST-C then introduces Ohm's Law.

OBJECTIVES:

The student will:

- state how current is affected by a change in voltage.
- state how current is affected by a change in resistance.
- state Ohm's Law and solve mathematical problems based on Ohm's Law.
- explain how a rheostat works.
- determine the relationship between current and resistance in a fixed-voltage circuit.

SEQUENCE: LA-C; ST-C

SUGGESTIONS:

1. It is recommended that the students perform LA-C prior to discussing the ST-C. Once the inverse nature of the relationship between resistance and current is understood, it should be easier for the students to master Ohm's Law.

2. In developing Ohm's Law, you may wish to review the concept of proportionality as related to graphing that was originally presented in Biomedical Mathematics, Unit I, Lesson 16. Consultation with the mathematics instructor is suggested; you may wish to consider team-teaching a lesson on Ohm's Law.

3. One day before LA-D, the students should be asked to bring in 1.5-volt batteries for testing (6-volt lantern and 9-volt transistor batteries are also acceptable--see Information on LA-D).

KEY--PROBLEM SET C:

1. voltage and resistance.

2. a. The current decreases.

   b. The current increases.

   c. The current decreases by a factor of two.

   d. The current decreases by a factor of four.

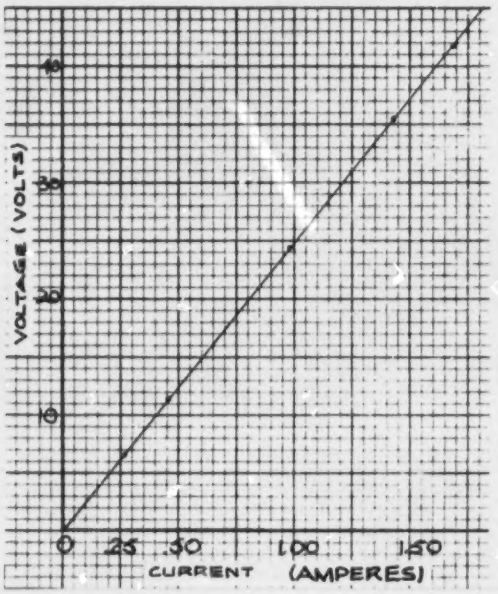
3. a.

b. .25 ampere

4. 40 ohms

5. 110 volts

6. a. (see graph at right)



b. R ≈ 24.9 ohms

c. I ≈ 0.06 ampere

7. a. 240 ohms

b. 0.05 ampere

c. 25 meters

8. a. at position A. b. 10 ohms c. 1 ampere d. ∿ 0.091 ampere

e. ∿ 0.167 ampere f. 10 volts g. 0 volts h. ∿ 9.1 volts

INFORMATION ON LABORATORY ACTIVITY C:

TEACHING NOTES:

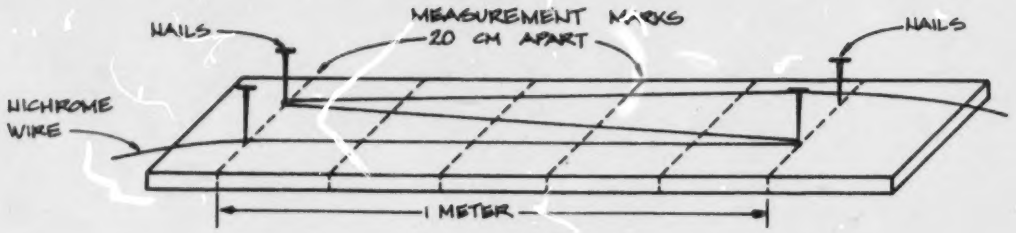
1. In this activity, the students have an opportunity to discover that the amount of current flowing in a circuit is inversely proportional to the resistance of the circuit. The BIP is used both as a voltage supply and an ammeter. The resistance is provided by a length of nichrome wire. The activity serves as an introduction to the concept of Ohm's Law which is treated in ST-C.

2. Anticipated time: 1 to 2 periods

2. The nichrome wire is available on order from most electronics or hardware stores. It is commonly used in toasters, hot plates, and similar appliances. The wire should be specified as "straight nichrome wire, 32-gauge." The resistance of the wire should be between 10 and 15 Ω/ft.

4. The input to the BIP null-point circuit is connected to a 10-Ω resistor, which is inside the BIP. This internal resistance (which is equivalent to approximately 23 cm of nichrome wire) introduces a significant error into the results of the activity. As may be seen in the Anticipated Results section, the graph of resistance versus 1/current does not pass through the origin, which is attributable to the internal resistance of the BIP. Another source of error is the effect of temperature on the resistance of the wire. As the current increases, the wire heats up slightly. The heating effects become more pronounced as the lengths of wire become shorter. This is the reason that the students are instructed not to make any readings with lengths of wire less than 140 cm. (In addition, the influence of the BIP internal resistance is also much more apparent as the wire becomes shorter.)

5. If there are not enough meter sticks available, a very simple substitute may be easily constructed which has certain advantages over the apparatus described in the procedure. A thin board approximately 110 cm long and four small nails are all that is required. The nails should be placed in the board one meter apart as shown in figure. The nichrome wire may then be looped around the nails. Marks placed 20 cm apart are helpful when length measurements are taken.



MATERIALS: (for 10 set-ups)

10 BIP's

31 meters (approximately 100 feet) nichrome wire, straight, 32-gauge

connecting wire

5 to 10 wire cutter-strippers

masking tape

10 meter sticks

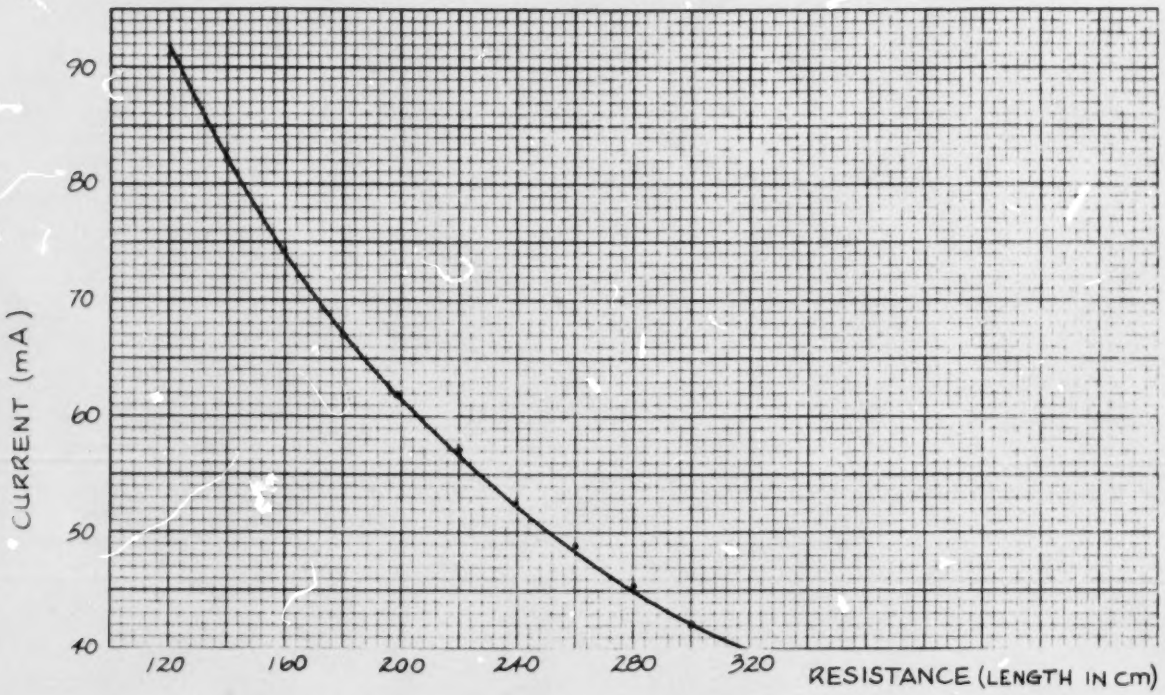
20 connecting wires, at least 60 cm long, with an alligator clip on one end

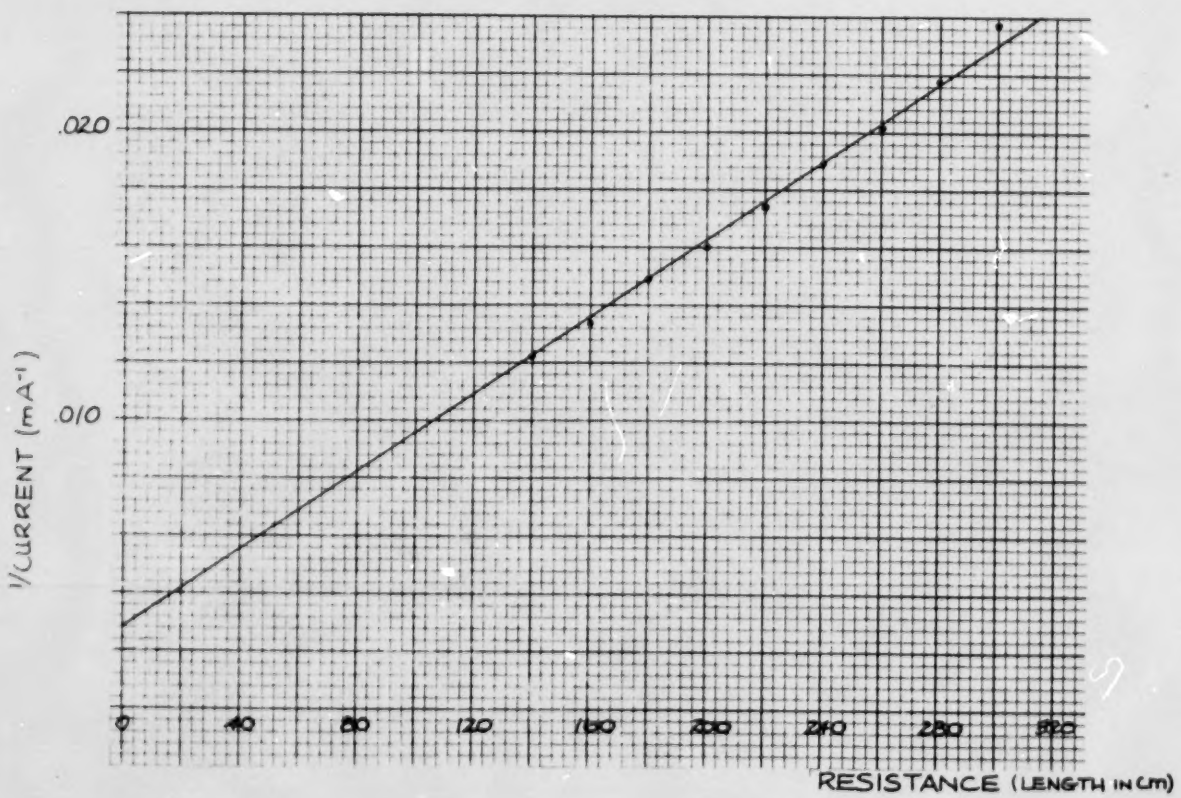
ANTICIPATED RESULTS:

The graphs obtained should demonstrate the inverse relation between current and resistance. Sample data and graphs are provided. The graph of current versus resistance is a hyperbolic curve. The inverse of current plotted against resistance shows an approximately linear relationship. As discussed in Teaching Note 4, the graph does not pass through the origin due to the internal resistance of the BIP and to heating effects in the nichrome wire.

SAMPLE DATA

Length (cm)	Current (mA)	$\frac{1}{\text{Current}}$ (mA^{-1})
300	42	.0238
280	46	.0217
260	49.5	.0202
240	53	.0189
220	57.5	.0174
200	62	.0161
180	67	.0149
160	74.5	.0134
140	82	.0122


90
80
70
60
50
40
CURRENT (mA)
120
160
200
240
280
320
RESISTANCE (LENGTH IN cm)


.020
.010
1/CURRENT (mA⁻¹)
0
40
80
120
160
200
240
280
320
RESISTANCE (LENGTH IN cm)

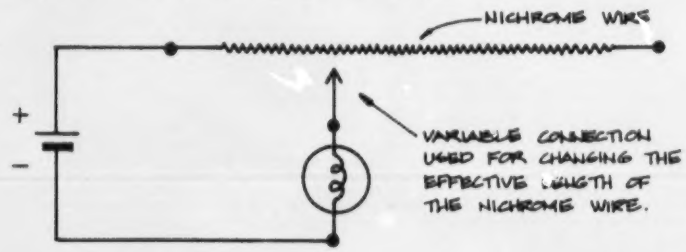
ANSWERS TO DISCUSSION QUESTIONS:

1. An increase in the length of the wire causes a decrease in the current. A decrease in wire length increases the current.

2. Inversely proportional. When the resistance is plotted against the inverse of the current, the graph is linear, which indicates an inverse relationship.

3. Doubling the resistance of a wire decreases the current by a factor of approximately two.

4. A variable length of nichrome wire may be connected as shown below. (This sort of arrangement is discussed in Section C-4.)



LESSON D: ELECTRICITY IN THE BODY

RATIONALE:

In this lesson, students' knowledge of electricity is expanded to include the role of electricity in the transmission of nerve impulses. The effects of electric shock are also discussed, in particular ventricular fibrillation and respiratory failure. In general, the lesson emphasizes the importance of electricity in all human physiology. LA-D provides experience with measurements of voltage and calculations of current and resistance.

OBJECTIVES:

The student will:

- state how voltages are produced in the body.
- list several ways in which the body makes use of electricity for its vital functions.
- list the two most common causes of fatal electric shock.

SEQUENCE: ST-D; LA-D (or reverse)

SUGGESTIONS:

1. The subject of nerve impulses is treated in Lesson 2. If the electricity lessons follow Lesson 2, you may wish to simply summarize Section D-1.

2. After the treatment of electricity in this and the preceding lessons, students may be better prepared to understand some of the earlier lessons involving electrical phenomena. Some examples of lessons which you may wish to have students reconsider include the one on ECG (Unit III, Lesson 8) and the one on electrostatics and charge (Unit I, Lesson 20).

3. It may be useful to point out that the shock discussed in Unit III, Lesson 22, is distinct from electrical shock. Shock as discussed in Unit III refers to a serious lowering of blood pressure and can result from many types of trauma (including electrical shock).

INFORMATION ON LABORATORY ACTIVITY D:

TEACHING NOTES:

1. In this activity, the students test the condition of 1.5-volt batteries using the BIP to measure voltage. The activity provides experience in the measurement and calculation of electrical quantities (voltage, current and resistance).

2. Anticipated time: 1 to 2 periods.

3. The procedure assumes that a number of batteries will be provided by the instructor. These batteries should be pre-tested prior to the activity, and marked with appropriate code numbers so that the students' results can be checked. (Note: AAA-size batteries are not suitable for this procedure and should be avoided.)

4. It is also assumed that students will bring in their own batteries from home. Batteries rated at voltages higher than 1.5 volts may also be tested if the correct external resistance is used. For example, a 6-volt lantern battery requires a 10-ohm, 5-watt resistor (a lantern battery produces much more power than a flashlight battery). A 9-volt transistor battery requires a 470-ohm, 1/4-watt resistor. A table rating the condition of these batteries based on their internal resistance is provided.

5. If a student should bring in a battery rated at greater than 10 volts, it could be tested without damaging the BIP. However, if it actually developed more than 10 volts, he would be unable to null the diode lights. By putting two of the test leads in series (end-to-end), voltages as high as 19 volts could be measured. The mA dial reading times 0.19 would then give the voltage. See the BIP Manual for more information regarding high-voltage measurement.

BATTERY SIZE	INTERNAL RESISTANCE (OHMS)		
	Good	Marginal	Very Weak
6-volt lantern	< 2.4	2.4 to 12	>12
9-volt transistor	< 90	90 to 450	>450

6. The activity may be simplified by omitting the calculations and implementing a simpler test--the students could rate the battery's condition based solely on the loaded voltage. As shown in the following table, the condition of a 1.5-volt battery should be rated as good if the loaded voltage is greater than 1.2 volts, marginal if between 0.8 and 1.2 volts, and very weak if less than 0.8 volts. Note that a different resistance must be used with each battery size. The resistors are all 1/4-watt unless otherwise indicated. The resistances specified are standard sizes and may be obtained at electronics stores.

BATTERY SIZE	EXTERNAL RESISTANCE	LOADED VOLTAGE		
		Good	Marginal	Very Weak
AA	10Ω	>1.2	0.8 to 1.2	< 0.8
C	4.7Ω	>1.2	0.8 to 1.2	< 0.8
D	3.3Ω	>1.2	0.8 to 1.2	< 0.8
6V lantern	10Ω, 5 watt	>4.8	3.2 to 4.8	< 3.2
9V transistor	470Ω	>7.2	4.8 to 7.2	< 4.8

7. If students have difficulty with getting the diode lights to null, check to make sure that the test leads are firmly connected to the battery terminals. Also make sure that the leads are not reversed.

8. A common curse of measuring devices is that they have some effect on what they are measuring. The BIP-voltage meter is no exception. When it is connected to a battery, the meter puts 10,000 ohms of resistance across the battery (9100 ohms in the test lead plus 1000 ohms inside the BIP). This resistance draws a small current and puts a small load on the battery. And when a battery is loaded, its voltage decreases some.

A simple calculation, though, shows that the load the voltage meter puts on a battery is slight enough to be ignored. With a 1.5-volt battery, the current through the 10,000-ohm resistance of the voltage meter amounts to

$$I = \frac{V}{R} = \frac{1.5}{10{,}000} = 0.00015 \text{ ampere}$$

But a D-size flashlight battery is designed to supply about half an ampere of current. So the load introduced by the meter is a negligible portion of the normal load.

MATERIALS: (for 10 set-ups)

- 10 BIP's
- connecting wire
- 10 test leads attached to 9.1K-ohm resistor (standard BIP-accessory item)
- 10 or more new 1.5-volt batteries of several varieties
- 10 or more used 1.5-volt batteries of several varieties
- 5 to 10 wire cutter-strippers
- tape
- 40 alligator clips, each with connecting pin (supplied as standard BIP accessories)
- 10 resistors, 10-ohms, 1/4 watt

ANTICIPATED RESULTS:

Sample data are shown in the data table.

The current in the circuit is calculated by dividing the loaded voltage (V_L) by the resistance (10 ohms). The result is in units of amperes. The internal resistance of the battery is calculated by dividing the internal voltage drop of the battery (V_{Int}) by the current.

$$\text{internal resistance of battery} = \frac{(V_{Int})\ (10 \text{ ohms})}{V_L}$$

Students should not regard the results of their tests as absolute. A battery rated as very weak may still function acceptably in certain low-drain circuits. (Note that Battery #3 on the following page was new, yet was rated as marginal. The reason for this is that it was a transistor battery designed for a smaller load than was applied during the test.) It should also be noted that some batteries may produce acceptable loaded voltages initially but weaken rapidly after several minutes of operation under load.

Battery Specifications:

BATTERY NUMBER	SIZE	MAKE AND MODEL	
1	C	flashlight	Ray-O-Vac #1C (used)
2	C	flashlight	Ray-O-Vac #1C (used)
3	C	transistor	RCA VS335 (new)
4	C	alkaline	RCA VS1335 (new)
5	D	flashlight (heavy duty)	Eveready #1250 (used)
6	D	flashlight	Eveready #950 (used)

Voltage, Internal Resistance, and Current:

BATTERY NUMBER	VOLTAGE UNLOADED (V_U)	VOLTAGE LOADED (V_L)	CURRENT IN AMPERES	INTERNAL VOLTAGE DROP (V_U-V_L)	INTERNAL RESISTANCE IN OHMS	CONDITION
1	1.3	0.8	.08	0.5	6.25	very weak
2	1.3	0.0	.00	1.3	very high	dead
3	1.6	1.4	.14	0.2	1.43	marginal
4	1.65	1.6	.16	0.05	0.31	good
5	1.6	1.55	.155	0.05	0.32	good
6	1.55	1.45	.145	0.1	0.69	marginal

ANSWERS TO DISCUSSION QUESTIONS:

1. In general, the voltages of used batteries should be less than the voltages of new batteries. However, some used batteries may show unloaded voltages that are comparable to those of new batteries.

2. As the battery runs down, its internal resistance increases.

3. As the battery runs down, the amount of current in the circuit decreases. The current is limited by the internal resistance of the battery. As the resistance increases, the current decreases.

4. If the fourth battery is replaced by a length of wire, the three batteries could be expected to deliver enough power to give fair reception. But with the dead battery in the circuit, no reception is the likely result. The high internal resistance of the dead battery limits the current too severely. An analogous situation is a two-cell flashlight with one new cell and one dead cell. No light is produced. Yet a single good cell generates a weak glow in a flashlight bulb.

LESSON E: ELECTRICAL SAFETY IN THE HOME

RATIONALE:

In order for the students to be familiar with the hazards of electrical systems, the nature of voltage supply lines in modern buildings is discussed, including topics such as alternating current and electrical wiring. Safety precautions that reduce the risk of electric shock and electrical fires are also discussed, since these two hazards are the most common problems in electrical safety. To complement some of the principles given in the Student Text, the students measure their skin resistance in LA-E.

OBJECTIVES:

The student will:

- distinguish between alternating and direct current.
- state the conditions under which an individual may receive a severe electric shock, and how such shocks may be prevented.
- explain how fuses and circuit breakers are used to limit current flow and prevent fires in a home.

SUGGESTIONS:

1. Electrical shock is a fairly common experience. In 1973, 1149 fatalities caused by electrical shock were reported. You might survey the class to determine what kinds of situations have led to electrical accidents in the students' experience. Could any of these accidents have been prevented? How?

2. The electronics instructor or an electrician could be invited to discuss aspects of electrical safety with the students.

KEY--PROBLEM SET E:

1. The resistance of the skin limits the current to a safe level. In order for a dangerous amount of current to flow (at least 15 mA), the skin resistance would have to be approximately 100 ohms ($\frac{1.5\ V}{100\ \Omega} = .015\ A$). Skin resistance values are much higher than this, and consequently a battery does not pose a hazard.

2. a. $\frac{100\ V}{.100\ A} = 1000\Omega$ b. $\frac{1\ V}{.100\ A} = 10\Omega$

3. a. In order for an electric current to flow, a potential difference must be present. Since the bird's feet are gripping the same high-voltage wire, there is no potential difference between its feet. Therefore there is no current flowing through the bird, even though the bird is at a potential of 10,000 volts.

b. Since the snake is touching the metal pole, which is connected to the ground, the snake must be at ground potential. When the snake touches the bird, there will be a path for the current. The current will flow from the 10,000-volt line through the bird and the snake, down the pole and into the earth.

4. a. Yes. Current flows from the defective switch, through Ima's body and into the earth through the puddle of water. Since the area of contact with the water is fairly large, the skin resistance is not enough to limit the amount of current to a safe level.

b. $\frac{120\ V}{6000\Omega} = .02\ A = 20\ mA$

c. The shock will probably not be fatal. Ima may have problems letting go of the switch, since currents of 16 mA or higher cause muscles to contract uncontrollably. Consequently, the shock will be a rather uncomfortable experience for Ima.

d. $\frac{120\ V}{10^{17}} = 1.2 \times 10^{-15}\ A$

e. Ima would have best avoided the accident by not standing in the puddle of water. This put her in direct contact with ground. Had her shoes been dry, they would have provided enough resistance to limit the current flow to a safe level.

5. a. When the wire landed on the car, the metal parts of the car immediately were at a potential of 5000 volts. Current does not flow through the car because the metal of the car is insulated from the ground by the rubber tires. Since Fred is not in contact with any grounded object, no current can flow from the wire through his body to the ground.

b. When Fred steps out of the car, he may be in big trouble. If he is touching any of the metal on the car that is at a 5000-volt potential when his foot touches the ground, he will provide a path for current to flow from the high-voltage wire, through the car, himself and into the ground. Fred is likely to suffer a dangerous shock. He can avoid this shock by making sure that he is not touching the car and the ground simultaneously; that is, by jumping out of the car.

INFORMATION ON LABORATORY ACTIVITY E:

TEACHING NOTES:

1. In this activity, the students measure the electrical resistance of the

skin for various areas of the body. The results complement the discussion of the hazards of electric shock in ST-E.

2. Anticipated time: 1 to 2 periods.

3. The electrocardiogram electrodes, supplied as standard equipment with the BIP, are suitable for use in this activity. It may be necessary to explain that the connection to each electrode lead should be made to the large central prong. It will not affect the results if the alligator clip is also touching the metal fringe that surrounds the central prong.

4. Caution the students to avoid using too much electrode paste. If too much paste is smeared around the electrode, the area of electrical contact becomes larger than the electrode, which results in resistance measurements that are too low (and mA dial readings that are too high).

5. The resistor used in the procedure is supplied as a standard BIP accessory and is rated at 5100 Ω, 1/4 watt (also available at electronics stores). This resistance coupled with a BIP internal resistance of 1000 Ω gives a total resistance of 6100 Ω, which serves to limit the amount of current to measureable levels. The resistance also limits the amount of current flowing through the body of the subject being tested. Even if the body offered no resistance, the current would still be limited to a safe level. Using Ohm's Law, the current may be calculated given that the voltage provided by the BIP is 6.1 V.

$$I = \frac{V}{R} = \frac{6.1\ V}{6100\Omega} = .001\ A$$

$$= 1\ mA$$

As discussed in Section D, one milliampere is enough to cause a tingling sensation, but not enough to be dangerous. Even though the skin offers additional resistance, the students should not be surprised to experience some sensation, particularly if the current is maintained for some time. It is extremely important that the students have only 5100-Ω resistors available to them. Accidental substitution of a resistor of lower value could cause an uncomfrotable amount of current to flow.

MATERIALS: (for 10 set-ups)

10 BIP's

connecting wire

5 to 10 wire cutter-strippers

10 resistors, 5100-Ω, 1/4-watt, with lead attached

30 alligator clips

20 electrodes (electrocardiogram type, supplied with the BIP)

100 ml acetone (in several small containers)

2 tubes electrode paste

cotton or absorbent tissue

5 to 10 screwdrivers

10 elastic bandages

ANTICIPATED RESULTS:

Sample results are shown on the sample data sheet on the following page.

Even without experimental errors, you should expect the "dry" contact to give quite variable results. On a cool, dry day the lack of perspiration should be expected to give much higher skin resistance than measurements on a hot, humid day. And, of course, individuals vary greatly in their perspiring characteristics. The "paste" contact should give more consistent results if properly done.

The predicted current with 120 volts should prove to be safe.

SAMPLE DATA SHEET:

SITE	ELECTRODE PASTE OR DRY	mA DIAL READING	TOTAL SKIN RESISTANCE (ohms)	SKIN RESISTANCE AT SITE (ohms)
forearm	paste	14	37,500	18,000
back of hand (same arm)	dry	6	95,600	76,800
back of hand (same arm)	paste	13	40,800	22,000
palm of hand (same arm)	dry	8	70,200	51,400
palm of hand (same arm)	paste	10	54,900	36,100
palm of other hand (other arm)	paste	10	54,900	36,100

Current through body with 120-volt power supply:

$$I = \frac{V}{R} = \frac{120\ V}{54{,}900\Omega} \simeq .0022 \text{ ampere}$$

$$= 2.2 \text{ mA}$$

ANSWERS TO DISCUSSION QUESTIONS:

1. Doubling the area of the current path increases the current flow by a factor of two. The resistance should be halved.

2. The area of contact with the electrodes is small compared to what might be encountered. Two moist feet on a concrete slab, for example, would show much less resistance than measured here. So would a moist hand grasping the metal handle of a power tool. Applying 120 volts to that handle (as could happen if the handle wasn't grounded) might easily send a current of more than 100 mA from the hand through the body to the feet and into the grounded slab.

3. As shown in the Anticipated Results for the "paste" readings, the resistance of the skin increases as the skin thickness increases. However, with the "dry" readings the palm shows a lower resistance than the back of the hand. This is apparently a result of the larger amount of sweat on the palm, which conducts better than the dry skin on the back of the hand.